# BEACH Program: Bacteria Trends at Core Marine Beaches, 2003-2014

DEPARTMENT OF ECOLOGY
State of Washington

December 2015
Publication No. 15-03-037

## Publication information

This report is available on the Department of Ecology's website at
https://fortress.wa.gov/ecy/publications/SummaryPages/1503037.html

The BEACH Program website is: http://www.ecy.wa.gov/programs/eap/beach

Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search Study ID, EPABEACH.

Ecology's Activity Tracker Code for this study is 02-502.

## Contact information

Author: Debby Sargeant and Evan Newell
Environmental Assessment Program
P.O. Box 47600
Olympia, WA 98504-7600

For more information contact:

Publications Coordinator
Environmental Assessment Program
P.O. Box 47600, Olympia, WA 98504-7600
Phone: (360) 407-6764

Washington State Department of Ecology - www.ecy.wa.gov

| | | |
|---|---|---|
| o | Headquarters, Olympia | (360) 407-6000 |
| o | Northwest Regional Office, Bellevue | (425) 649-7000 |
| o | Southwest Regional Office, Olympia | (360) 407-6300 |
| o | Central Regional Office, Union Gap | (509) 575-2490 |
| o | Eastern Regional Office, Spokane | (509) 329-3400 |

**Cover photo**: Enjoying a day at a Mukilteo beach (photo by Department of Ecology)

# BEACH Program: Bacteria Trends at Core Marine Beaches, 2003-2014

by

Debby Sargeant and Evan Newell

Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

Water Resource Inventory Areas (WRIAs) and 8-digit Hydrologic Unit Code (HUC) numbers:

WRIAs

- 1: Nooksack
- 3: Lower Skagit/Samish
- 5: Stillaguamish
- 6: Island
- 7: Snohomish
- 8: Cedar/Sammamish
- 9: Duwamish/Green
- 10: Puyallup/White
- 12: Chambers/Clover
- 13: Deschutes
- 14: Kennedy/Goldsborough
- 15: Kitsap
- 16: Skokomish/Dosewallips
- 17: Quilcene/Snow
- 18: Elwha/Dungeness
- 19: Lyre/Hoko
- 20: Soleduc
- 22: Grays Harbor

HUC numbers

- 17110002
- 17110004
- 17110008
- 17110019
- 17110018
- 17110020
- 17110021
- 17100101
- 17100106

*This page is purposely left blank*

# Table of Contents

# List of Figures and Tables

Page

## Figures



## Tables



.

# Abstract

The Beach Environmental Assessment, Communication, and Health (BEACH) Program is an ongoing monitoring and notification program throughout Puget Sound and the coast of Washington State. Washington marine beaches are tested for the fecal bacteria, enterococci, to determine possible health risk to the public from water contact recreation. The program began with a pilot project in 2003.

The BEACH program consistently monitors 51 core beaches. These beaches were selected as the highest-use and highest-risk beaches in Washington. Data from the core beaches were analyzed to determine if there were any long-term trends in marine water quality based on summer bacteria data from 2003 through 2014.

Results indicate that the core beaches overall show no significant bacteria trends in water quality for the period tested. Individual core beaches were tested for bacteria trends over time and showed mixed results.

Increasing trends in bacterial levels were detected at the following beaches:

- Bayview State Park beach in Skagit County.
- Dash Point Metro Park beach in Pierce County.
- Freeland County Park beach in Island County.

Decreasing trends in bacteria levels were detected at the following beaches:

- Richey Viewpoint beach in King County.
- Howarth Park beach in Snohomish County.

Recommendations include working with Skagit and Island Counties to determine possible sources of bacteria to Bayview State Park and Freeland County Park.

# Acknowledgements

The authors of this report thank the following people for their contributions to this study:

- All of our BEACH Program Partners
- Washington State Department of Ecology staff:
  - Julianne Ruffner
  - Christopher Clinton
  - Carol Maloy
  - Bob Cusimano
  - Jessica Archer

This project has been funded wholly, or in part, by the U.S. Environmental Protection Agency (EPA) under the BEACH Monitoring and Notification Program Implementation Grants, Grant Agreement Federal Award Identifier CU-00J75501; and an EPA DOH Puget Sound Restoration Grant, Federal Grant Award PC-00J32601 with the Washington State Department of Ecology. The contents of this document do not necessarily reflect the views and policies of EPA, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

# Background

The Beach Environmental Assessment, Communication, and Health (BEACH) Program supports a marine recreational beach monitoring and notification program throughout the Puget Sound and coast of Washington. Washington marine beaches are tested for the fecal bacteria, enterococci, to determine possible health risk to the public from water contact recreation. During the swimming season (Memorial Day through Labor Day each year), water samples are collected at high-use, high-risk marine beaches primarily used for swimming, wading, surfing, and SCUBA diving. The public is notified when results exceed the BEACH Program Guidance thresholds described in Schneider (2002).

The BEACH Program is an ongoing monitoring program that began with a pilot project in 2003. The program distributes grant funding for monitoring, beach notification, and public education to local health jurisdictions (LHJs), universities, tribes, and volunteer non-profit organizations throughout Puget Sound and the coast. Monitoring and program activities are coordinated on a regional basis by BEACH Program staff.

## Study Area

In early 2004, after the initial pilot project, the BEACH program developed a list of 51 core beaches (Figure 1 and Appendix B). Core beaches are considered to be the highest-use and highest-risk beaches in Washington. The BEACH Program strives to consistently monitor core beaches, as funding allows, to maximize the protection of public health from water contact risks with the additional benefit of having a continuous data set to determine long-term water quality trends.

## Purpose

Both Results Washington−the Governor's initiative to ensure a more efficient, effective, and transparent state government−and the Puget Sound Partnership report on marine beach bacterial effects on water quality as a measure of water quality improvement in Puget Sound and Washington. In previous years the number of swimming beach closure and advisories has been used as a measure of how our beaches are doing. A beach closure occurs when a local health department closes the beach to water contact recreation due to high bacteria levels or a sewage spill. A beach advisory is issued in response to increased bacteria levels; children, elderly, and those in ill health are advised not to swim.

In 2014, out of 65 beaches sampled (both Washington State and Makah BEACH Programs), 88% had fewer than two swimming advisories or closures during their respective sampling seasons. Figure 2 presents the percentage of beaches that had fewer than two swimming advisories or closures each year. The percentage of beaches passing (meeting the swimming criteria) in 2014 was higher than the yearly average of 84%.

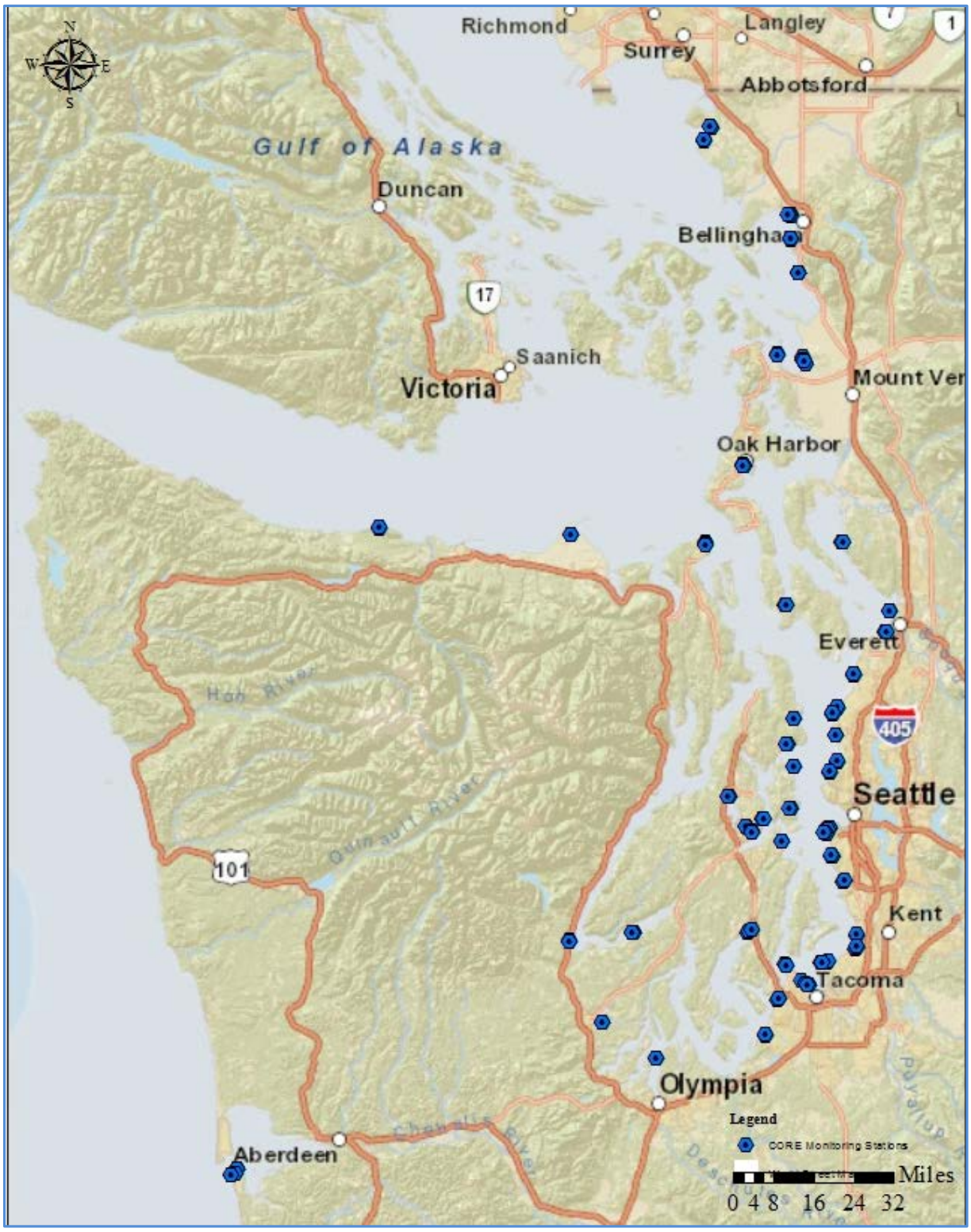



Figure 1. BEACH Program monitoring study area, showing the 51 CORE monitoring stations.

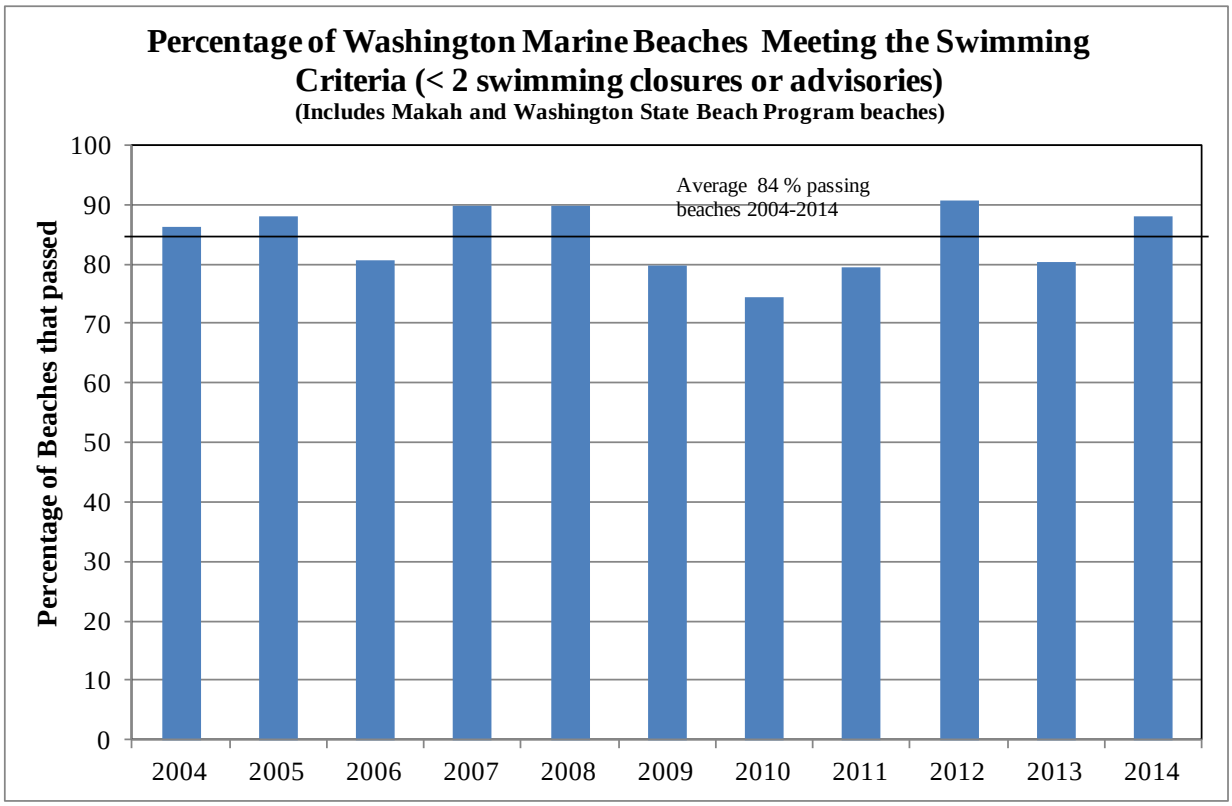



Figure 2. Percentage of Washington State marine beaches meeting the Swimming Criteria, 2004-2014.

Another way to determine if marine beach water quality is improving or getting worse is to look at bacteria trends over time at the core beaches. The core beaches have the longest term record of bacteria monitoring during the summer months (2003-2014). The purpose of this report is to present results of bacterial trend analysis for the core marine beaches.

## Study Design and Methods

The study area includes public marine beaches in Puget Sound and the coast. The number of monitored beaches varies from year to year, depending on available funding. The BEACH program sampled from 46 to 71 beaches per year from 2004-2014. Coastal counties currently participating in the program are: Clallam, Grays Harbor, Island, Jefferson, King, Kitsap, Mason, Pierce, Skagit, Snohomish, Thurston, and Whatcom.

### Parameters of Interest

To determine if marine water is safe for primary contact recreation, the U.S. Environmental Protection Agency (EPA) recommends monitoring for the fecal bacteria indicator, enterococci, in marine and freshwater, or *Escherichia coli* (*E. coli)* in freshwater. Enterococci is thus the

primary parameter of interest for this marine beach monitoring program. Studies show a link between illness and fecal contamination in recreational waters (EPA, 2012).

### Regulatory Criteria or Standards

Currently the BEACH Program's water quality decision criteria are based on EPA's ambient water quality criteria (EPA, 1986), not the Washington State Water Quality Standard for fecal coliform bacteria (FC). The fecal bacteria, enterococcus, is used because this indicator has a better correlation between indicator levels and illness rates in marine water than either FC or *E. coli*. The current Washington State Water Quality Standard for primary contact recreation in marine water is for FC, and the criteria and indicator are based on protecting shellfish for human consumption.

Numeric criteria for the BEACH Program are as follows:

- Geometric mean (GM) shall not exceed 35 enterococci/100 mL; based on results from a minimum of five weekly samples (including all samples).

The minimum beach swimming advisory level or Beach Action Value (BAV) protective bacterial standard for marine recreational beaches used for primary contact recreation is as follows:

- The beach arithmetic average (of the three samples collected at a single beach) for the sample day should not exceed 104 enterococci/100 mL.

The critical warning level (Beach Swimming Closure) protective bacteriological standard for marine recreational beaches used for primary contact recreation is as follows:

- The beach arithmetic average for the sample day should not exceed 276 enterococci/100 mL.

## Sample Sites and Frequency

Core beaches sampled from 2003 through 2014 were included in the trend analysis. Out of 51 core beaches, trend analysis was conducted on 50 of the core beaches. One core beach, Bayview Boat Launch beach, was not included due to too few sample events during the swimming season. Appendix A describes the core beaches and the years they were sampled. Most sites were sampled weekly from mid-May through the end of August.

## Field Procedures and Laboratory Analysis

A full description of field procedures and laboratory analysis is included in the *Quality Assurance Project Plan: BEACH Program* (Schneider, 2004). For each sample event, three sites at each beach were sampled. Bacteria samples were obtained by grab sample in approximately 2.5 feet of water. Samples were immediately placed on ice and delivered to the laboratory for analysis within 6-24 hours. Sample containers were delivered pre-sterilized by the laboratory.

A number of microbiology laboratories were used for sampling. Laboratories were chosen based on State accreditation for enterococci bacteria methods and proximity to the beach sample sites. A list of laboratories and the enterococcus method used is described in Table 1.

Table 1. Laboratories conducting enterococci bacteria analysis and methodologies used for the BEACH Program, 2003-2014.

| County | Laboratory | Enterococci Method |
|---|---|---|
| Clallam | Clallam County Environmental Laboratory, Port Angeles | ASTM D6503 |
| | Twiss Analytical Laboratories Inc., Poulsbo | ASTM D6503 |
| Grays Harbor | Grays Harbor County Water Testing Lab, Montesano | ASTM D6503 |
| Island | Edge Analytical Laboratories Microbiology Lab, Bellingham | ASTM D6503 |
| | Skagit County Health Department Water Lab, Mount Vernon | ASTM D6503 |
| Jefferson | Twiss Analytical Laboratories Inc., Poulsbo | ASTM D6503 |
| King | King County Environmental Laboratory, Seattle | ASTM D6503 |
| | Water Management Laboratories Inc., Tacoma | EPA 1600 |
| | Tacoma-Pierce County Health Department Lab, Tacoma | EPA 1600 |
| Kitsap | Twiss Analytical Laboratories Inc., Poulsbo | ASTM D6503 |
| | Kitsap County Health District Laboratory, Bremerton | ASTM D6503 |
| | Lab/Cor Inc., Bremerton | ASTM D6503 |
| Mason | Mason County Public Health Laboratory, Shelton | ASTM D6503 |
| | Thurston County Health Department Laboratory, Olympia | ASTM D6503 |
| Pierce | AM Test Laboratories, Kirkland, WA | EPA 1600 |
| | Water Management Laboratories Inc., Tacoma | EPA 1600, ASTM D6503 |
| Skagit | Edge Analytical Laboratories Microbiology Laboratory, Bellingham | ASTM D6503 |
| | Skagit County Health Department Water Laboratory, Mount Vernon | ASTM D6503 |
| Snohomish | Everett Environmental Laboratory, Everett | ASTM D6503 |
| | Skagit County Health Department Water Laboratory, Mount Vernon | ASTM D6503 |
| Thurston | Thurston County Health Department Laboratory, Olympia | ASTM D6503 |
| Whatcom | Avocet Environmental Testing, Bellingham | ASTM D6503 |
| | Edge Analytical Laboratories Microbiology Laboratory, Bellingham | ASTM D6503 |

## Data Quality

All laboratories used for analysis were accredited by the Washington State Department of Ecology (Ecology) for the enterococci method specified. Each laboratory enters data into the BEACH database via Secure Access Washington (SAW). Database results are verified with the laboratory sheets within two weeks of data entry.

Field replicates were obtained to determine sample precision. To measure precision the percent relative standard deviation (%RSD) between field replicate pairs was calculated. The %RSD is calculated by taking the difference of the two samples and dividing by their mean, and multiplying by 100, and expressing the results as a percent. An Ecology report, *Replicate Precision for 12 TMDL Studies and Recommendations for Precision Measurement Quality Objectives for Water Quality Parameters* (Mathieu, 2006), proposes the following measurement quality objectives (MQOs) for bacteria: 50% of the replicate pairs must be at or below 20% RSD, and 90% of the pairs must be at or below 50% RSD.

The MQO results by laboratory for the 2003-2014 period are described in Table 2. All laboratories achieved the MQO of 50% of the replicate pairs below 20% RSD. The Grays Harbor County Water Testing Laboratory was the only laboratory to meet the MQO of 90% of the pairs at or below 50% RSD.

The average for 90% of the replicate pairs for all laboratories (2003-2014) was 82% RSD (for ≥10 replicates). For the replicate pairs with high %RSD values, results for over half of these replicate pairs were ≤50 MPN\100 mL. The greater the number of replicate pairs, the more accurately the %RSD statistic can predict variability. Also with this statistic there is greater variability with low results (Mathieu, 2006).

While low field replicate results may skew MQO results toward higher variation, the BEACH Program field replicates still do not meet MQOs as recommended by Mathieu (2006). This may be due to a difference in methodology and bacterial indicator. The Mathieu recommendations are based largely on the fecal coliform bacteria (FC) parameter and the membrane filter method of bacterial analysis.

Table 2. BEACH Program % relative standard deviation (RSD) by laboratory, 2003-2014.

| Laboratory | County | Period Used | No. Replicates | 50% of pairs ≤ to: | 90% of pairs ≤ to: |
|---|---|---|---|---|---|
| AM Test Laboratories, Kirkland, WA | Pierce | 2003 | 20 | 18% RSD | 143% RSD |
| Avocet Environmental Testing | Whatcom | 2004-2013 | 201 | 9% RSD | 76% RSD |
| Clallam County Environmental Laboratory | Clallam | 2004-2014 | 534 | 0% RSD | 71% RSD |
| Edge Analytical Laboratories | Skagit, Whatcom | 2009-2014 | 104 | 0% RSD | 100% RSD |
| Everett Environmental Laboratory | Snohomish | 2005-2014 | 252 | 0% RSD | 102% RSD |
| Grays Harbor County Water Testing Lab | Grays Harbor | 2003-2014 | 187 | 0% RSD | 33% RSD |
| King County Environmental Laboratory | King | 2004-2014 | 218 | 0% RSD | 68% RSD |
| Kitsap County Health District Laboratory | Kitsap | 2003-2005 | 3 | Min=0% RSD | Max=194% RSD |
| Lab/Cor Inc. | Kitsap | 2012-2014 | 79 | 0% RSD | 68% RSD |
| Mason County Public Health Laboratory | Mason | 2004-2008 | 108 | 0% RSD | 67% RSD |
| Skagit County Health Dept Water Laboratory | Skagit | 2003-2008 | 29 | 0% RSD | 67% RSD |
| Thurston County Health Department Laboratory | Thurston | 2004-2014 | 228 | 0% RSD | 100% RSD |
| Twiss Analytical Laboratories Inc. | Jefferson | 2004-2014 | 429 | 0% RSD | 92% RSD |
| Water Management Laboratories Inc. EPA Method 1600 | Pierce | 2004-2008 | 37 | 0% RSD | 100% RSD |
| Water Management Laboratories Inc. ASTM D6503 | Pierce | 2009-2014 | 111 | 0% RSD | 67% RSD |

## Data Analysis

The Regional Kendall test for trend was used to determine if bacterial water quality at core beaches as a whole has changed from 2003-2014. This test looks at trends across a region (Puget Sound and coastal core beaches) that are composed of multiple sample sites. The trend test was computed in the statistical package R (R Development Core Team, 2008).

Trend analysis was conducted using the beach geometric mean (GM) and estimated $90^{th}$ percentile for the beach season\year (Memorial through Labor Day sampling). The GM and $90^{th}$ percentile were calculated using sample data. Field and laboratory duplicates were not included in this analysis. Values below the enterococci bacteria reporting limit (RL) were assigned a value of (RL-1); values above the reporting limit were assigned a value of (RL+1).

To determine changes over time at individual core beaches, correlation analysis was conducted using the seasonal GM and $90^{th}$ percentile data to determine if bacteria levels had changed over time. The statistical package R was used to calculate Spearman's rho correlation statistics.

# Results

Results of the Regional Kendall test for trend showed no trend either increasing or decreasing bacteria levels at the core beaches region-wide. The results of the trend test are presented in Table 3.

Table 3. Regional Kendall test for bacteria trend at core beaches, 2003-2014.

| Statistic | 2 sided P value | Slope | Number of core beaches tested |
|---|---|---|---|
| Geometric mean | 0.26 | 0.04 | 50 |
| 90$^{th}$ Percentile | 0.13 | 0.28 | 50 |

Correlation analysis was used to determine the association between individual core beach bacteria levels over time. Spearman's rho was used to examine the relationship between both the geometric mean (GM) and 90$^{th}$ percentile enterococcus levels over time.

Table 4 presents the correlation results for the core beaches that had significant changes in bacteria levels over time ($p \leq 0.05$, 2-tailed test).

Table 4. Spearman's rho correlation results for core beaches with increasing or decreasing bacteria levels.

| Beach | No. Years Sampled | Statistic | Correlation Coefficient (Spearman rho) | Trend |
|---|---|---|---|---|
| Bayview State Park (Skagit County) | 11 | GM | 0.76 p< 0.01 | Increasing GM and 90$^{th}$ %tile |
| | | 90$^{th}$ %tile | 0.73 p=0.02 | |
| Dash Point Metro Park (Pierce County) | 8 | GM | 0.71 p=0.06 | Increasing 90$^{th}$ %tile |
| | | 90$^{th}$ %tile | 0.76 p=0.04 | |
| Freeland County Park (Island County | 12 | GM | 0.62 p=0.04 | Increasing GM and 90$^{th}$ %tile |
| | | 90$^{th}$ %tile | 0.69 p=0.02 | |
| Richey Viewpoint (King County) | 7 | GM | -0.86 p=0.02 | Decreasing GM and 90$^{th}$ %tile |
| | | 90$^{th}$ %tile | -0.86 p=0.02 | |
| Howarth Park Beach (Snohomish County) | 11 | GM | -0.74 p=0.01 | Decreasing GM |
| | | 90$^{th}$ %tile | -0.43 p=0.19 | |

Increasing bacteria levels over time were seen at Bayview State Park beach in Skagit County and Freeland County Park beach in Island County. Both beaches had increasing GM and 90$^{th}$ percentile bacterial levels. Dash Point Metro Park beach in Pierce County had increasing 90$^{th}$ percentile bacteria levels over time.

During the swimming season (Memorial Day through Labor Day), Bayview State Park beach has numerous swimming closures and advisories due to high bacteria levels. Freeland County Park beach has a permanent swimming advisory, and swim closures are often posted during the swimming season. Bacteria levels at Dash Point Metro Park beach are generally low. This beach was only closed for swimming once for high bacteria levels, in 2013.

Decreasing bacteria levels over time were seen at Richey Viewpoint in King County, both in the GM and 90$^{th}$ percentile. Decreasing GM bacteria levels were seen at Howarth Park beach in Snohomish County.

# Conclusions and Recommendations

## Conclusions

The BEACH Program core beaches show no significant overall trend in bacterial water quality as a whole for 2003 through 2014, neither increasing nor decreasing trends.

Decreases in bacteria levels over time are seen at the following core beaches:

- Richey Viewpoint beach in King County.
- Howarth Park beach in Snohomish County.

Increases in bacteria levels over time are seen at the following core beaches:

- Bayview State Park beach in Skagit County.
- Dash Point Metro Park beach in Pierce County.
- Freeland County Park beach in Island County.

Most laboratories did not meet the measurement quality objective (MQO) of 90% of the field replicate pairs at or below 50% relative standard deviation (RSD).

## Recommendations

- Continue monitoring core beaches yearly for possible trends in bacterial water quality.
- Work with Skagit and Island Counties to determine possible bacterial sources to beaches with increasing trends and swimming closures.
- Track field replicate variability by laboratory and by year to determine acceptable MQOs for enterococci most probable number method.

# References

APHA (American Public Health Association), American Water Works Association, and Water Environment Federation, 2012. Standard Methods for the Examination of Water and Wastewater 22nd Edition. American Public Health Association, Washington, D.C.

EPA, 1986. Ambient Water Quality Criteria for Bacteria – 1986. EPA 440/5-84-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC. http://water.epa.gov/scitech/swguidance/standards/upload/2001_10_12_criteria_ambientwqc_bacteria1986.pdf

EPA, 2012. Recreational Water Quality Criteria. EPA 820-F-12-058. U.S. Environmental Protection Agency, Office of Water, Washington, DC. http://water.epa.gov/scitech/swguidance/standards/criteria/health/recreation/upload/RWQC2012.pdf.

Mathieu, N., 2006. Replicate Precision for Twelve Total Maximum Daily Load (TMDL) Studies and Recommendations for Precision Measurement Quality Objectives for Water Quality Parameters. Washington State Department of Ecology, Olympia, WA. Publication No. 06-03-044. https://fortress.wa.gov/ecy/publications/SummaryPages/0603044.html

R Development Core Team, 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Schneider, L., 2002. DRAFT: Beach Environmental Assessment, Communication, and Health (BEACH) Program Guidance. Environmental Assessment Program, Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-050. https://fortress.wa.gov/ecy/publications/SummaryPages/0203050.html

Schneider, L., 2004. Quality Assurance Project Plan: BEACH Program. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-205. https://fortress.wa.gov/ecy/publications/SummaryPages/0403205.html

# Appendices

*This page is purposely left blank*

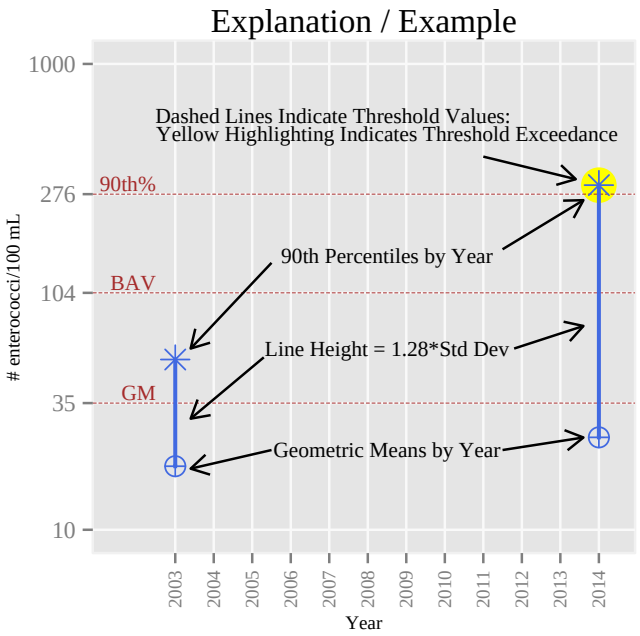
# Appendix A. Core Beaches and Sampled Years, 2004-2014

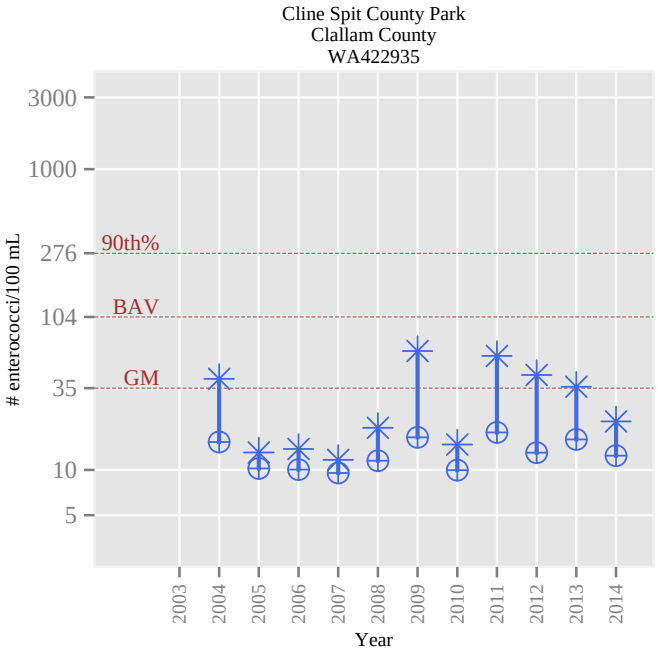
| County | Beach | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | Years Sampled |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clallam | Cline Spit County Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Clallam | Salt Creek Recreation Area | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Grays Harbor | Westhaven State Park, Half Moon Bay | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Grays Harbor | Westhaven State Park, South Jetty | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Grays Harbor | Westport, The Groynes | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Island | Freeland County Park/Holmes Harbor | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Island | Windjammer Lagoon | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Island | Windjammer Park Beach | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Jefferson | Fort Worden State Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| King | Alki Beach Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| King | Carkeek Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| King | Dash Point State Park | X | X | X | | | X | | X | | | X | 6 |
| King | Golden Gardens Beach | X | X | X | X | X | X | X | X | X | X | X | 11 |
| King | Lincoln Park Beach | X | X | X | X | X | X | X | X | X | X | X | 11 |
| King | Redondo County Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| King | Richey Viewpoint | X | X | X | X | X | X | | X | | | | 7 |
| King | Richmond Beach Saltwater Park | X | X | X | X | | X | | X | | | X | 7 |
| King | Saltwater State Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| King | Seahurst Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Kitsap | Arness County Park | X | X | X | X | X | X | | X | X | X | X | 10 |
| Kitsap | Eagle Harbor Waterfront Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Kitsap | Evergreen Park | X | X | X | X | X | X | X | X | | X | X | 10 |
| Kitsap | Fay Bainbridge Park | | X | X | X | X | X | X | X | X | X | X | 10 |
| Kitsap | Illahee State Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Kitsap | Indianola Dock | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Kitsap | Lions Field | X | X | X | X | X | X | | X | X | X | X | 10 |
| Kitsap | Pomeroy Park - Manchester Beach | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Kitsap | Silverdale Waterfront Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Mason | Potlatch State Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Mason | Twanoh State Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Mason | Walker County Park | | X | X | X | X | X | | X | | X | X | 8 |
| Pierce | Dash Point County Park | X | X | | | | X | | X | X | X | X | 7 |

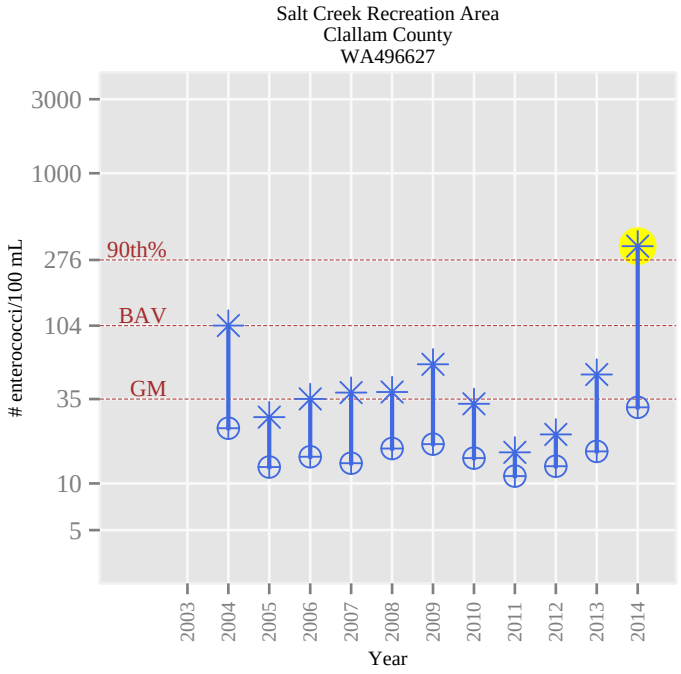
| County | Beach | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | Years Sampled |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pierce | Owen Beach/ Point Defiance Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Pierce | Purdy Sandspit County Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Pierce | Sunnyside Beach Park | X | X | X | X | X | X | | X | X | X | X | 10 |
| Pierce | Titlow Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Pierce | Waterfront Dock/Ruston Way | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Skagit | Bayview Boat Launch | X | X | X | X | X | X | | X | X | X | | 9 |
| Skagit | Bayview State Park | X | X | X | X | X | X | | X | X | X | X | 10 |
| Snohomish | Edmonds Marina Beach Dog Park | X | X | X | X | X | X | | | | | | 6 |
| Snohomish | Edmonds Marina Beach Park | | X | X | X | X | X | X | X | X | X | X | 10 |
| Snohomish | Edmonds Underwater Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Snohomish | Howarth Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Snohomish | Jetty Island | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Snohomish | Kayak Point County Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Snohomish | Picnic Point County Park | X | X | X | X | X | X | X | X | X | X | X | 11 |
| Thurston | Burfoot County Park | X | | X | | X | X | X | X | X | X | X | 9 |
| Whatcom | Birch Bay County Park | | X | X | X | X | X | X | X | X | X | X | 10 |
| Whatcom | Birch Bay State Park | X | X | X | X | X | X | | | | | | 6 |
| Whatcom | Larrabee State Park | | X | | X | X | X | X | X | X | X | X | 9 |
| Whatcom | Port of Bellingham Marina Beach | | | | X | X | X | X | X | X | X | X | 8 |

# Appendix B. Core Beach Enterococcus Graph Summaries, 2003-2014

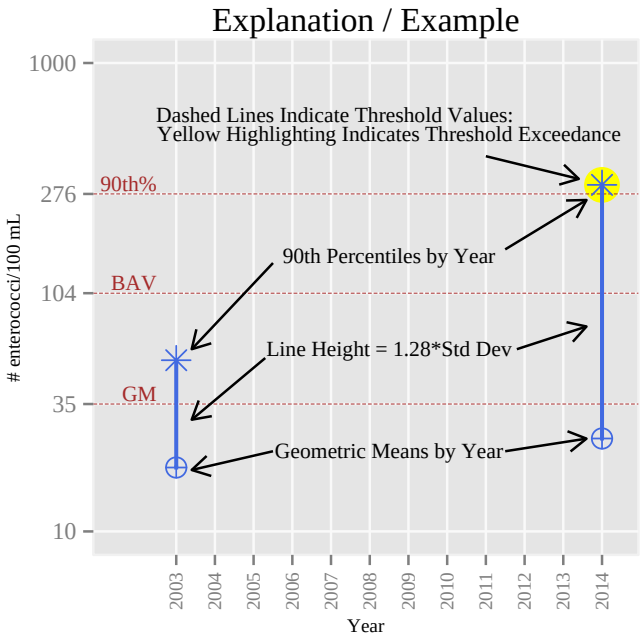
## *Clallam County*

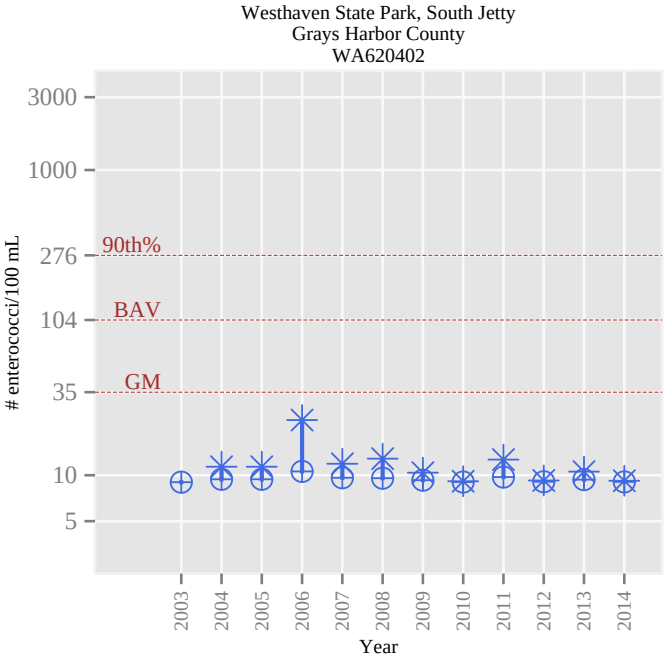


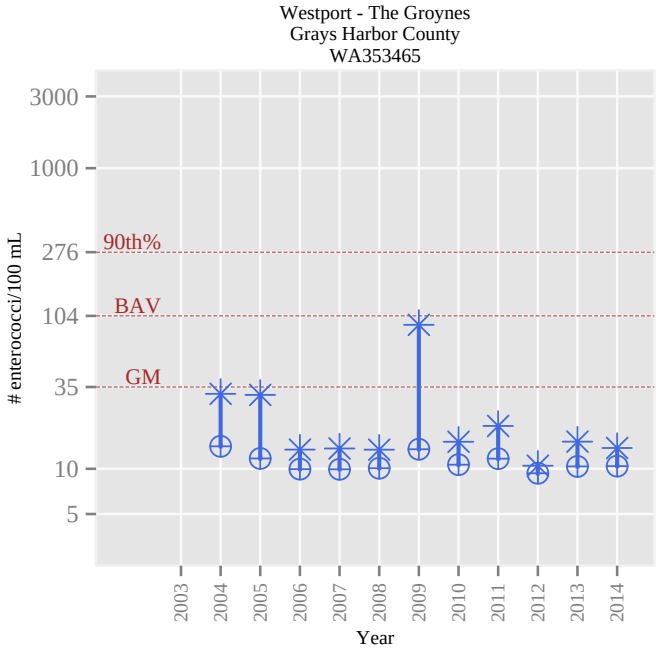



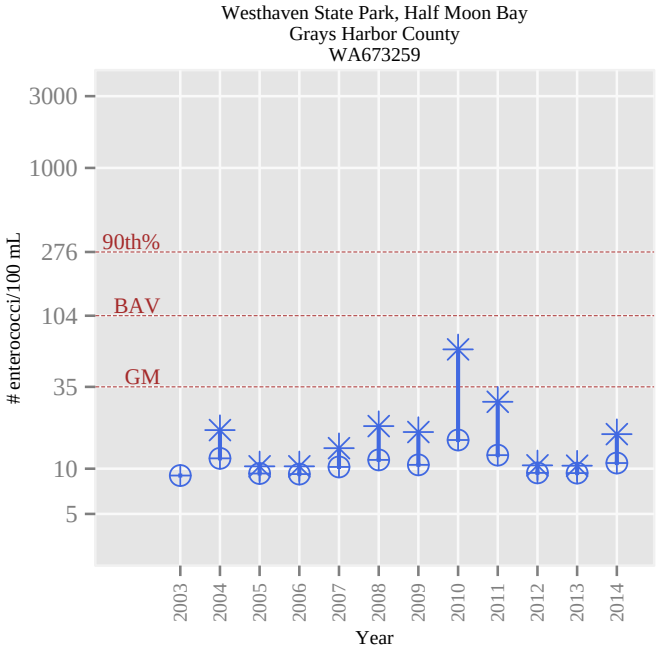



## *Grays Harbor County*

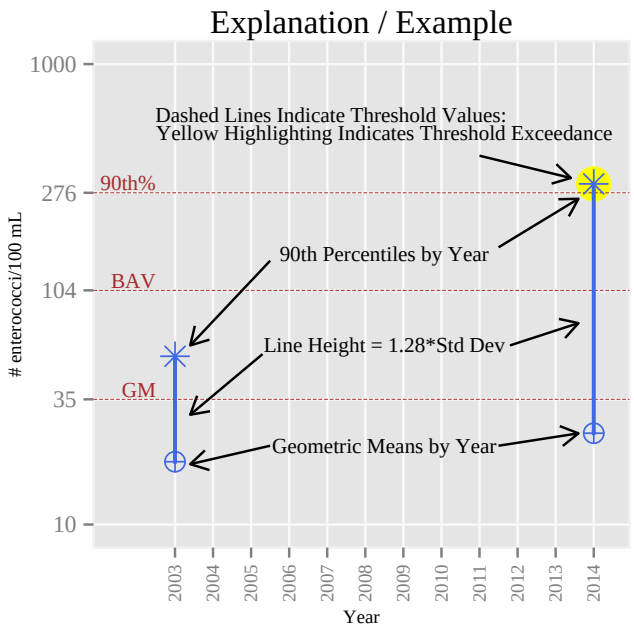


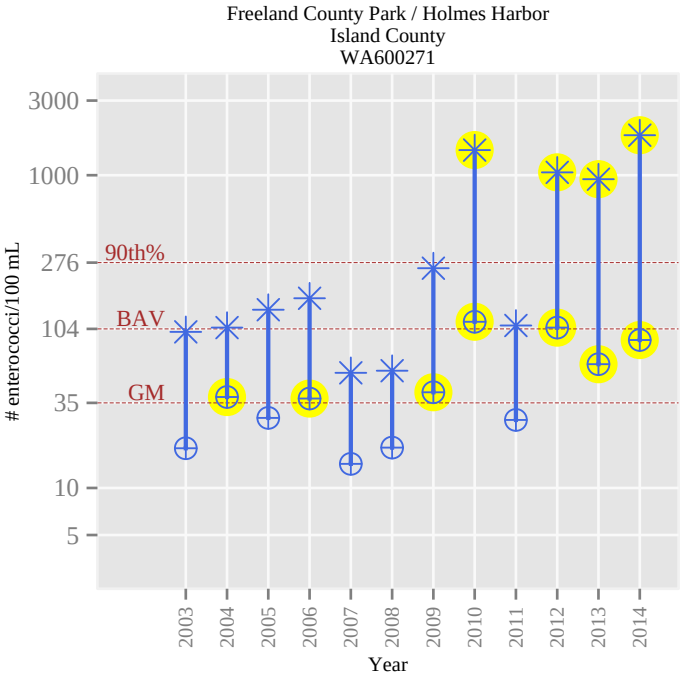



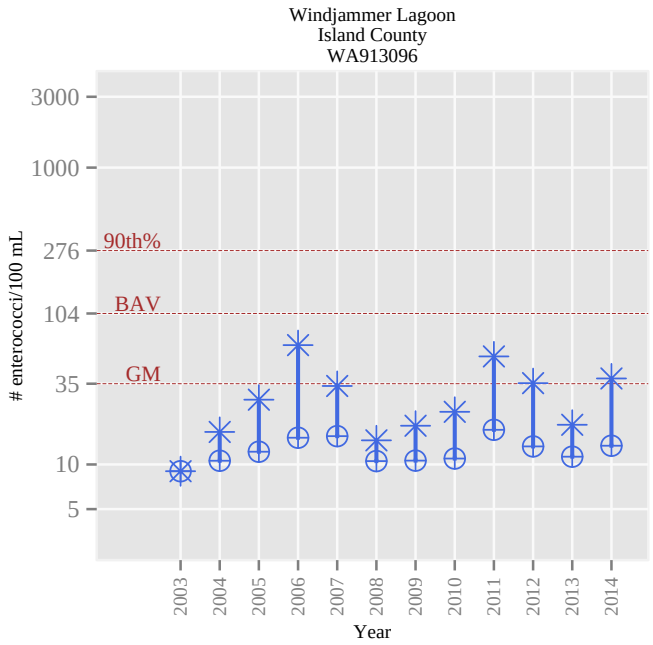



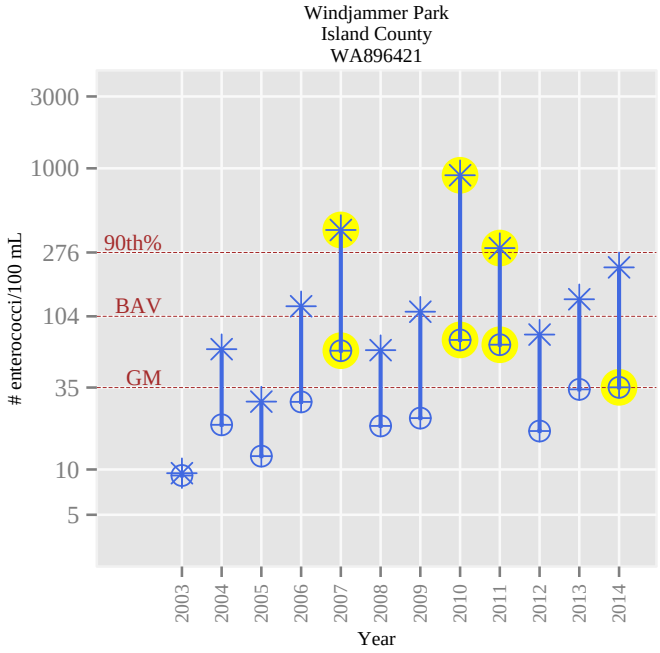



***Island County***

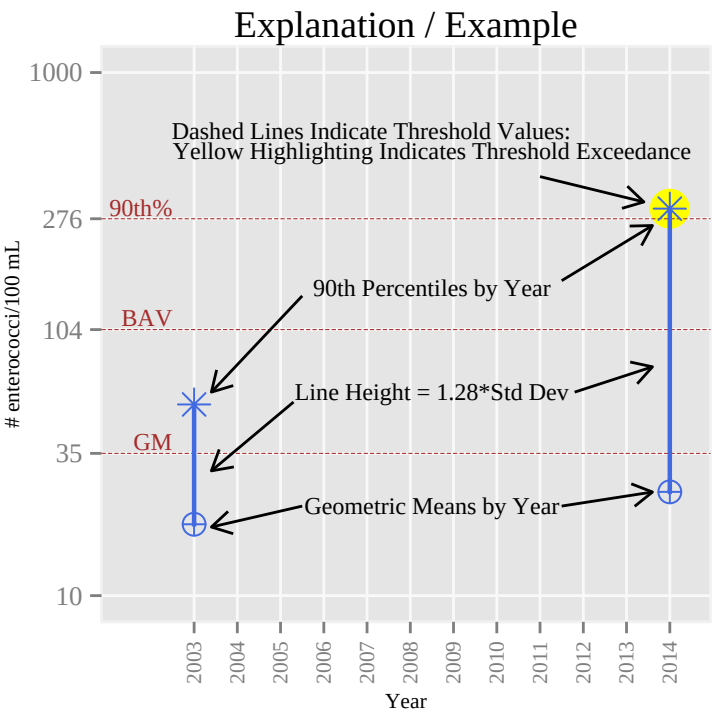


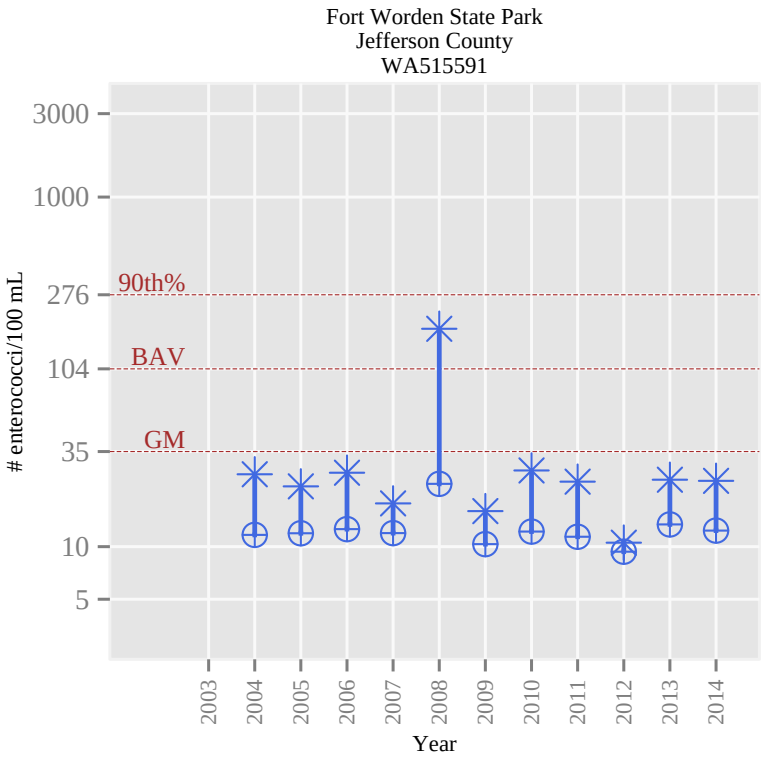



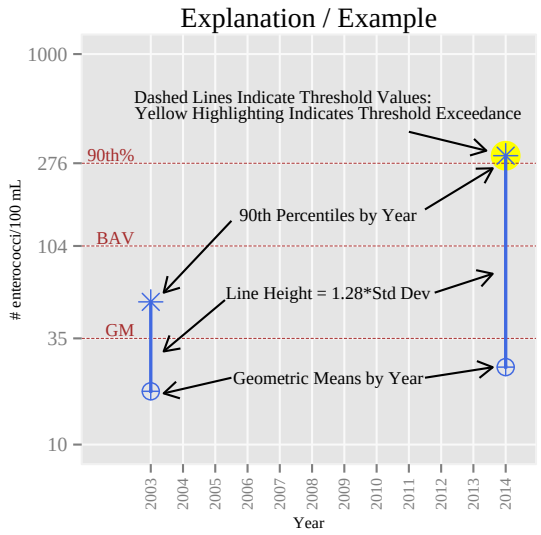



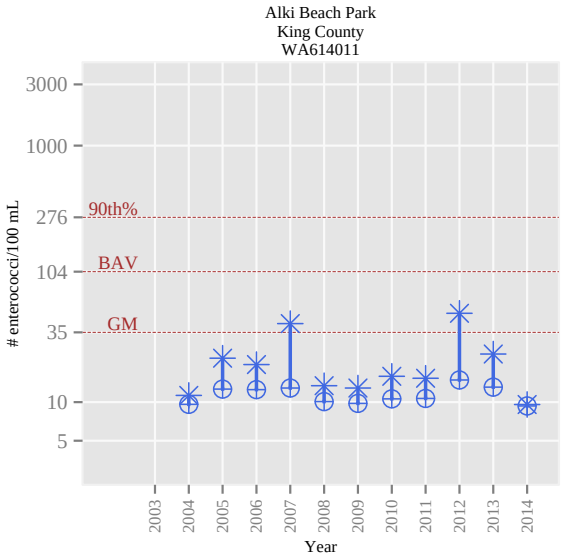
***Jefferson County***

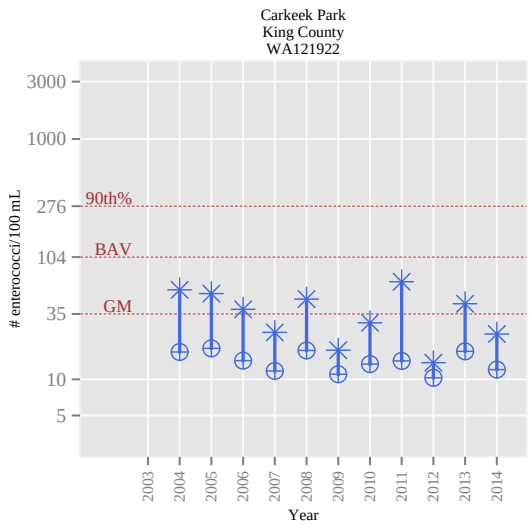


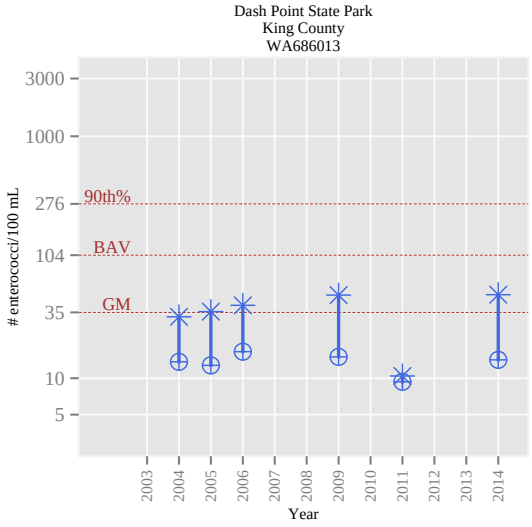



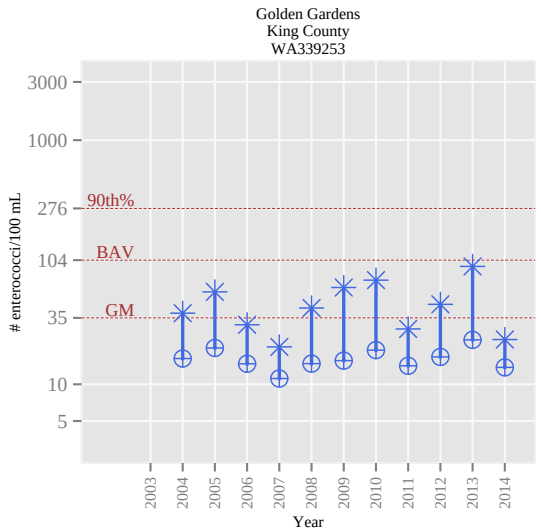
## *King County*

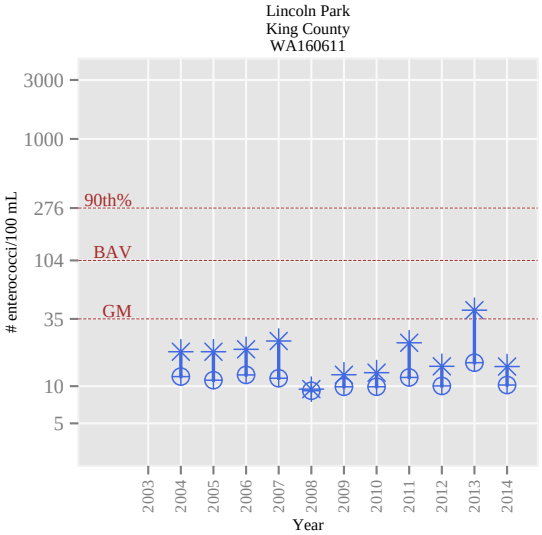

Explanation / Example
Dashed Lines Indicate Threshold Values:
Yellow Highlighting Indicates Threshold Exceedance
90th Percentiles by Year
Line Height = 1.28*Std Dev
Geometric Means by Year
90th%
BAV
GM
# enterococci/100 mL
Year

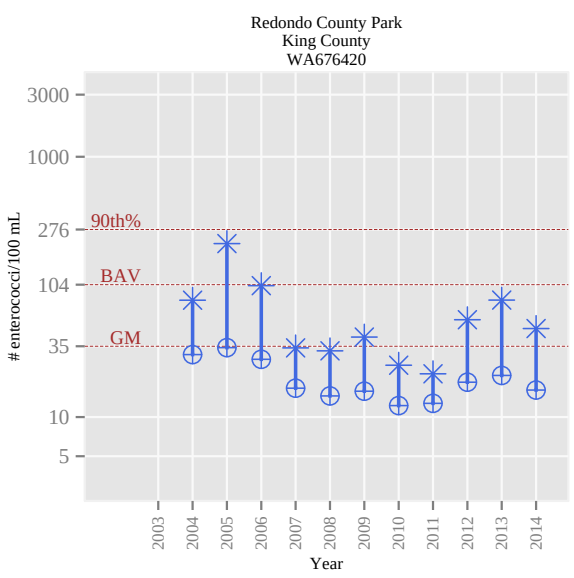

Alki Beach Park
King County
WA614011
90th%
BAV
GM
# enterococci/100 mL
Year

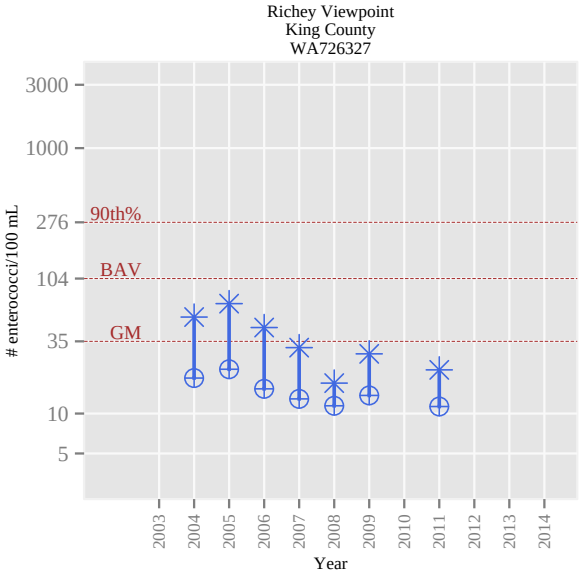

Carkeek Park
King County
WA121922
90th%
BAV
GM
# enterococci/100 mL
Year

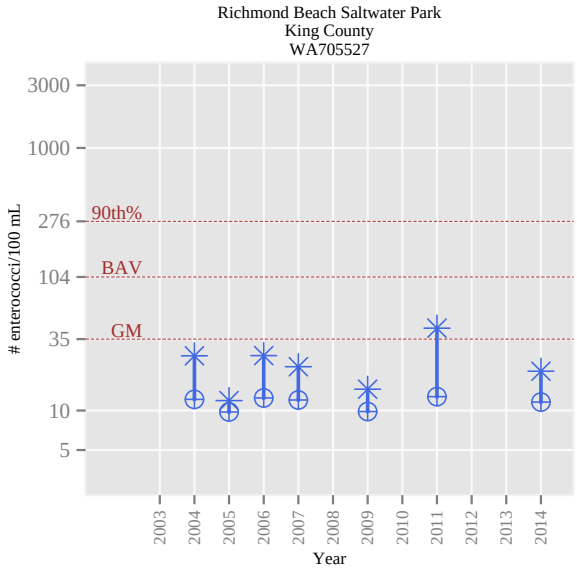

Dash Point State Park
King County
WA686013
90th%
BAV
GM
# enterococci/100 mL
Year

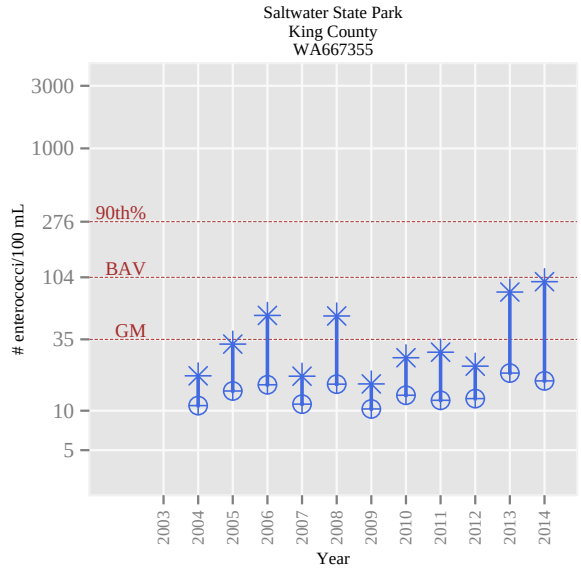

Golden Gardens
King County
WA339253
90th%
BAV
GM
# enterococci/100 mL
Year

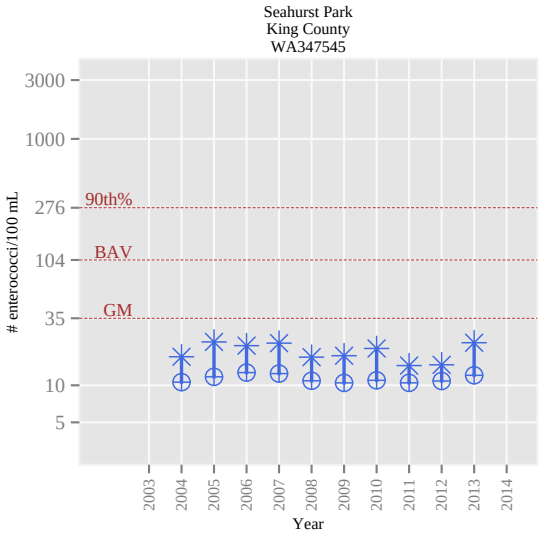

Lincoln Park
King County
WA160611
90th%
BAV
GM
# enterococci/100 mL
Year


Redondo County Park
King County
WA676420
# enterococci/100 mL
3000
1000
276
104
35
10
5
90th%
BAV
GM
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

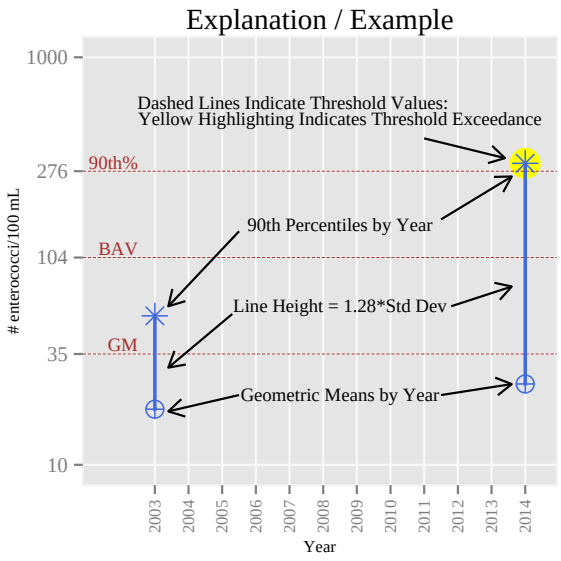

Richey Viewpoint
King County
WA726327
# enterococci/100 mL
3000
1000
276
104
35
10
5
90th%
BAV
GM
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

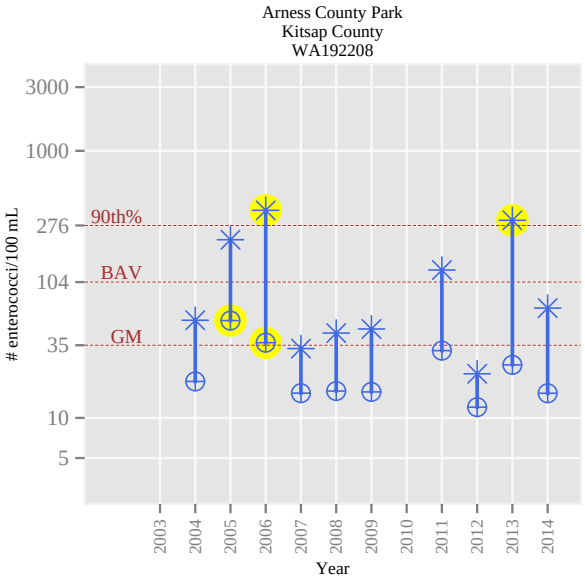

Richmond Beach Saltwater Park
King County
WA705527
# enterococci/100 mL
3000
1000
276
104
35
10
5
90th%
BAV
GM
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

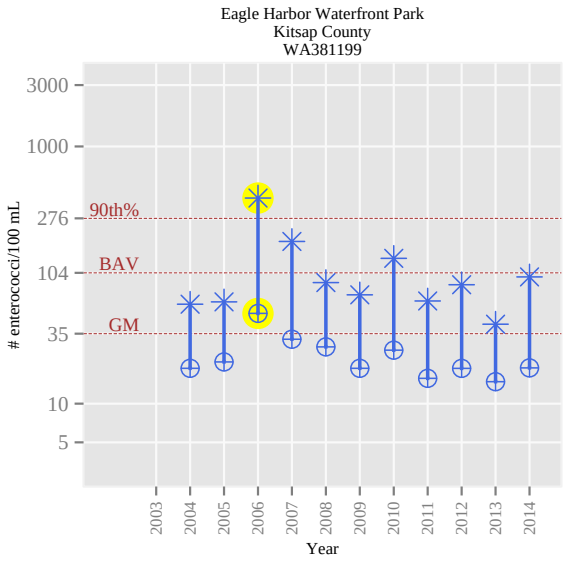

Saltwater State Park
King County
WA667355
# enterococci/100 mL
3000
1000
276
104
35
10
5
90th%
BAV
GM
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

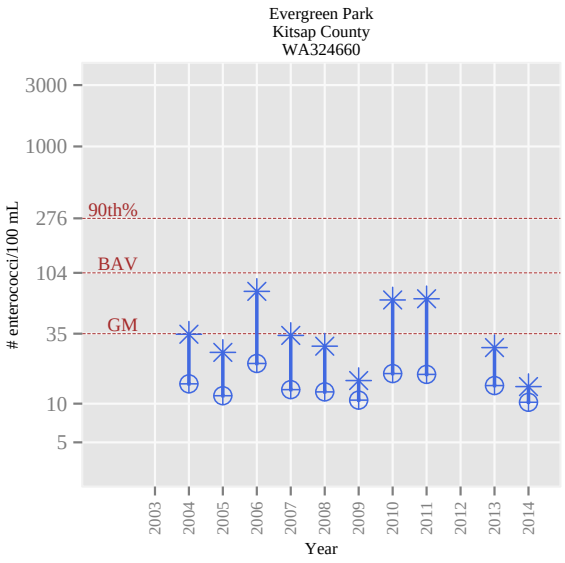

Seahurst Park
King County
WA347545
# enterococci/100 mL
3000
1000
276
104
35
10
5
90th%
BAV
GM
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

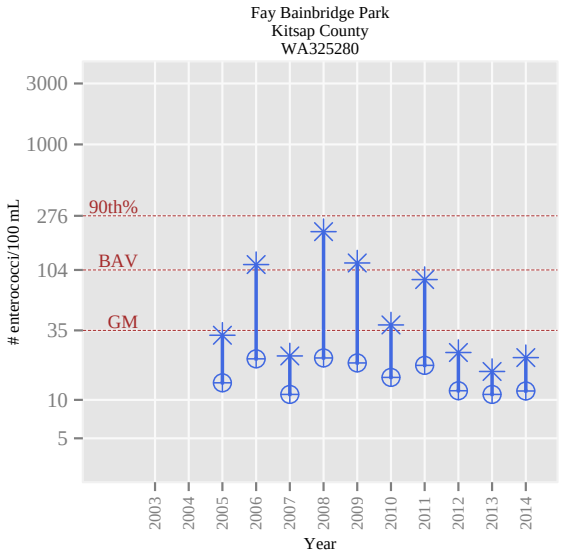
## *Kitsap County*

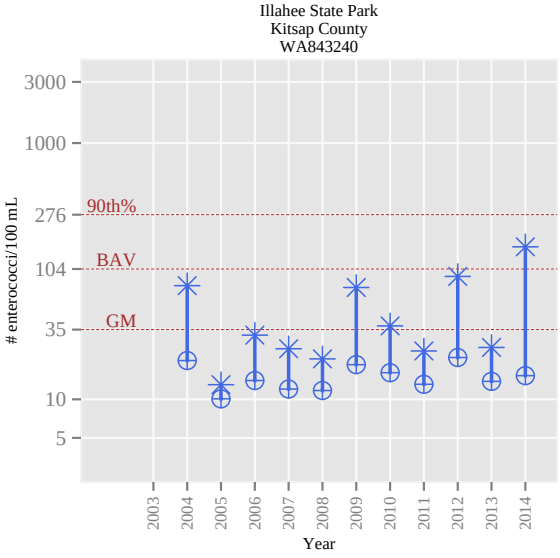


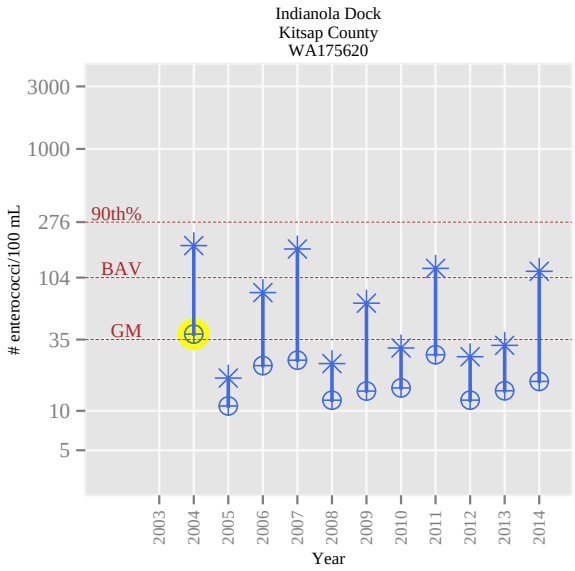



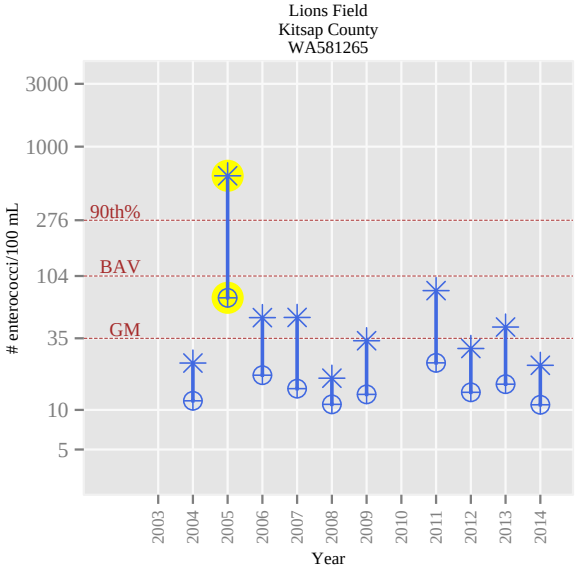

Eagle Harbor Waterfront Park
Kitsap County
WA381199
3000
1000
276
104
35
10
5
90th%
BAV
GM
# enterococci/100 mL
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

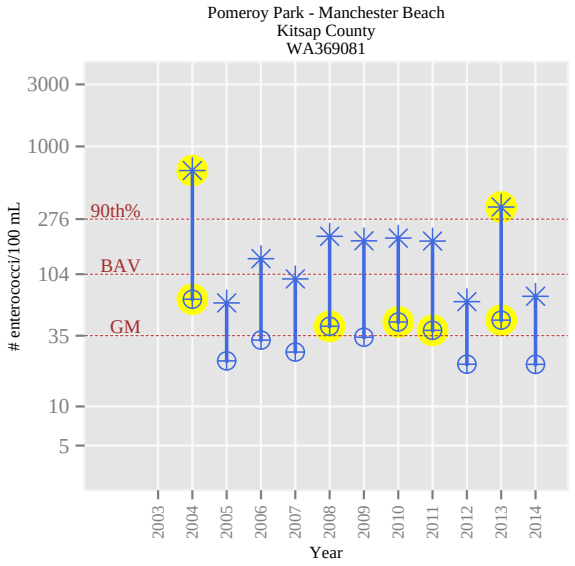

Evergreen Park
Kitsap County
WA324660
3000
1000
276
104
35
10
5
90th%
BAV
GM
# enterococci/100 mL
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

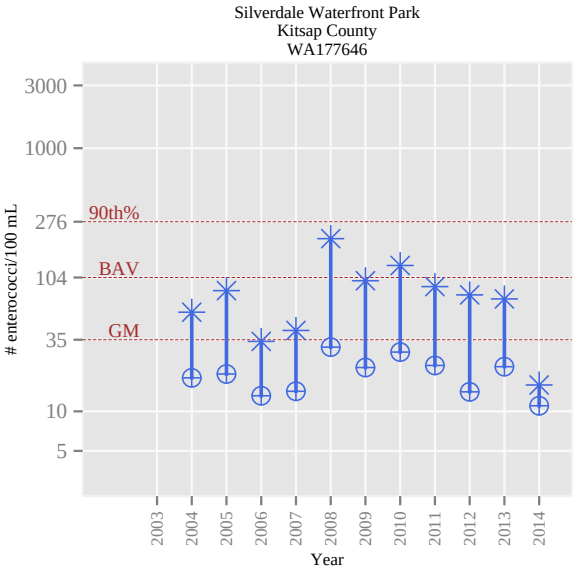

Fay Bainbridge Park
Kitsap County
WA325280
3000
1000
276
104
35
10
5
90th%
BAV
GM
# enterococci/100 mL
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year


Illahee State Park
Kitsap County
WA843240
3000
1000
276
104
35
10
5
90th%
BAV
GM
# enterococci/100 mL
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

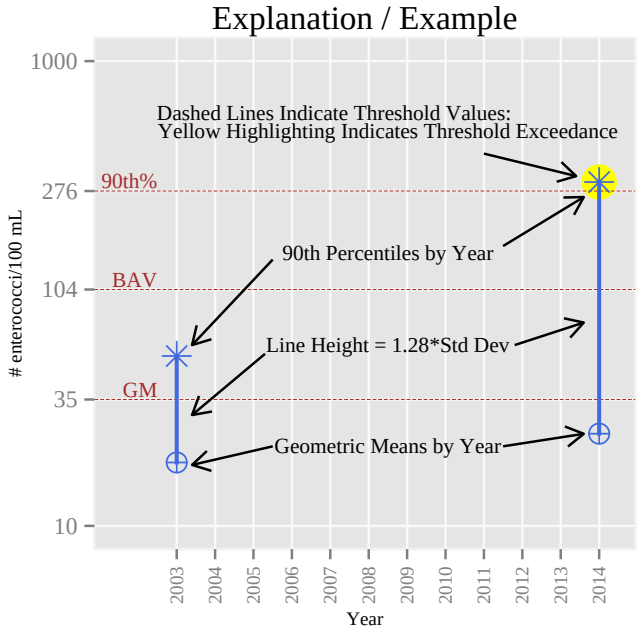

Indianola Dock
Kitsap County
WA175620
# enterococci/100 mL
3000
1000
276
104
35
10
5
90th%
BAV
GM
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

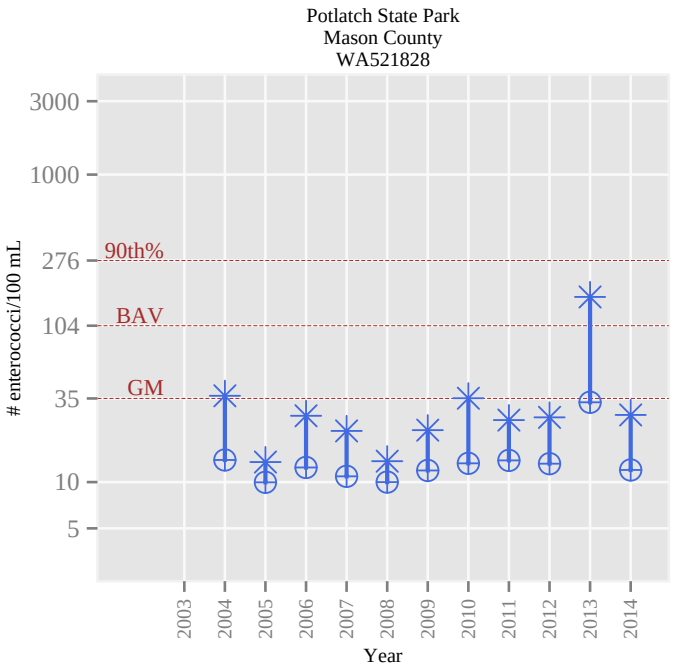

Lions Field
Kitsap County
WA581265
# enterococci/100 mL
3000
1000
276
104
35
10
5
90th%
BAV
GM
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

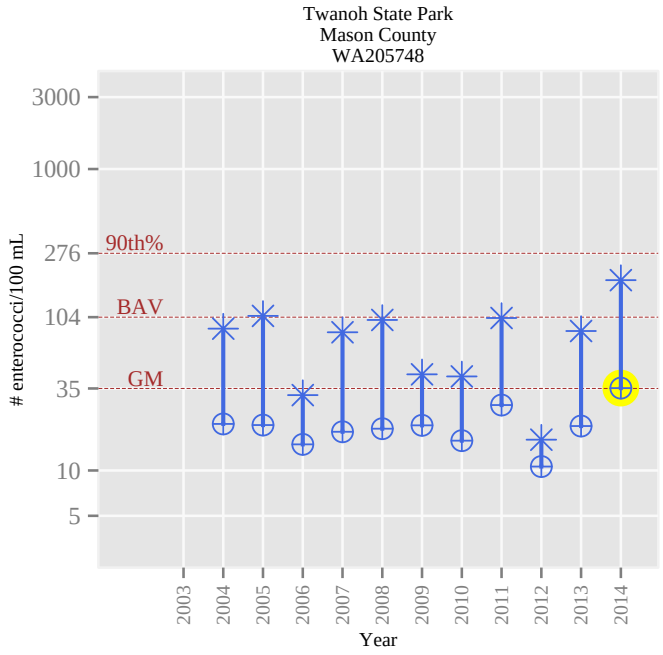

Pomeroy Park - Manchester Beach
Kitsap County
WA369081
# enterococci/100 mL
3000
1000
276
104
35
10
5
90th%
BAV
GM
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

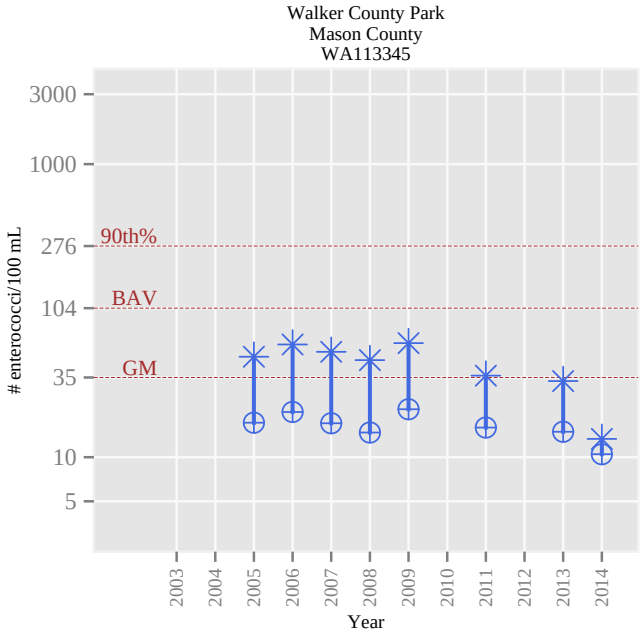

Silverdale Waterfront Park
Kitsap County
WA177646
# enterococci/100 mL
3000
1000
276
104
35
10
5
90th%
BAV
GM
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

***Mason County***

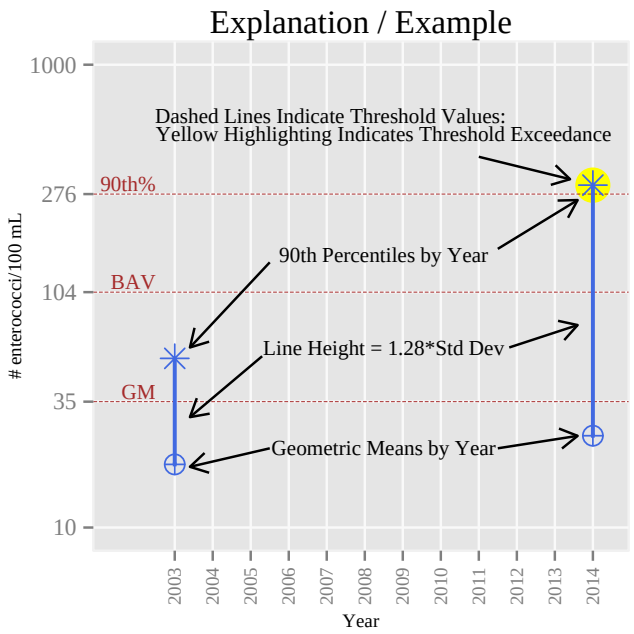


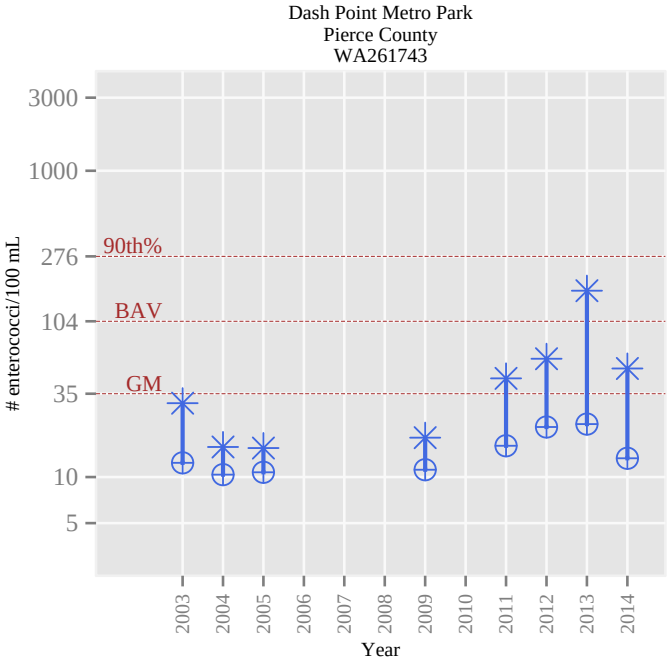



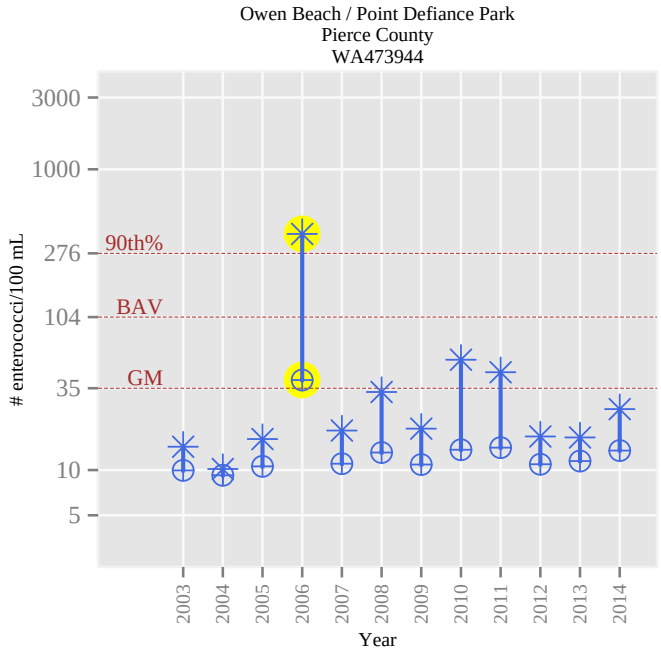



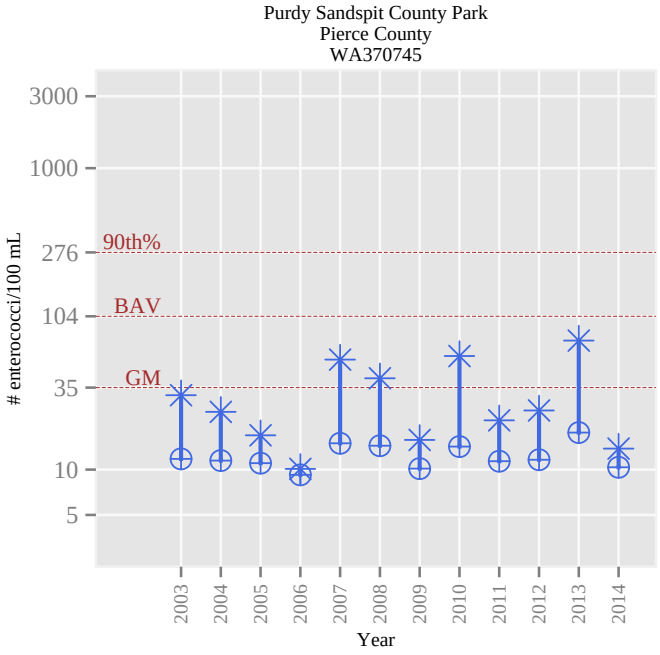



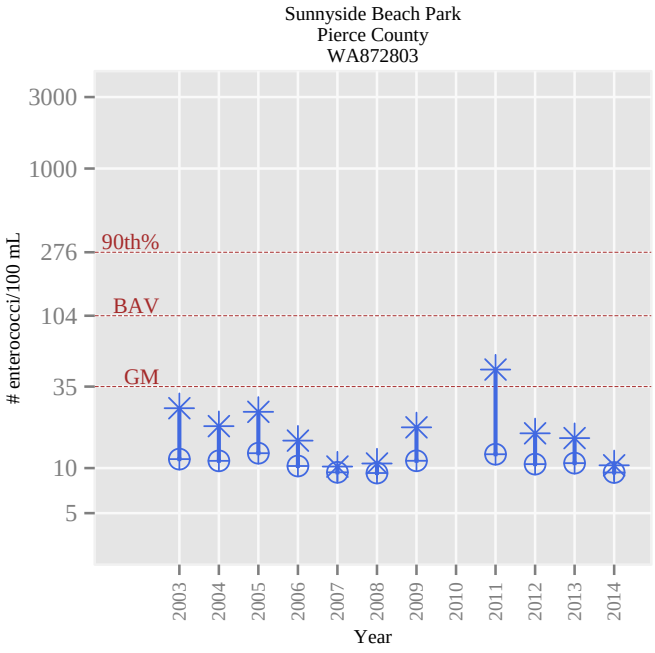
***Pierce County***

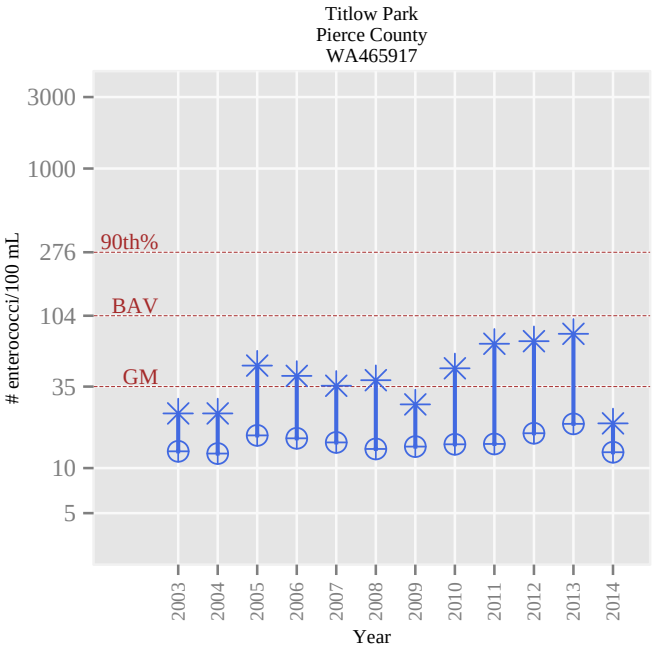


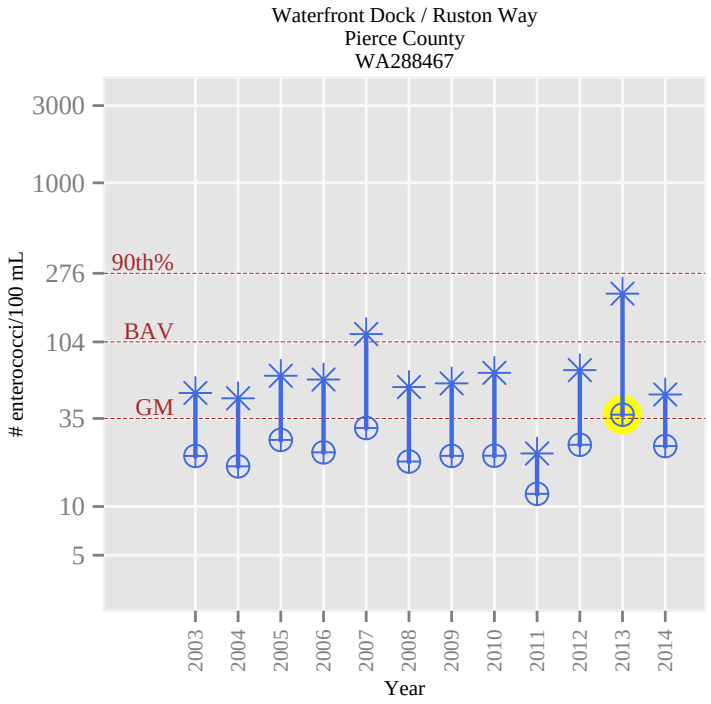



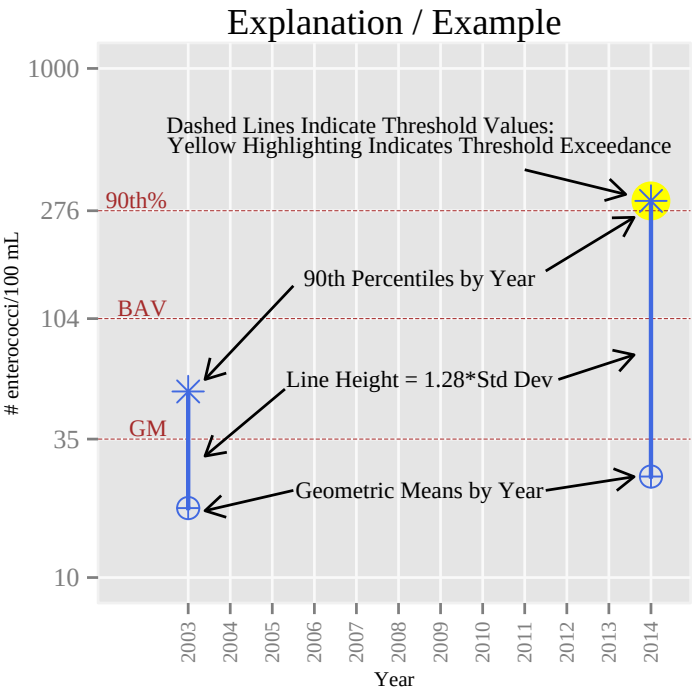



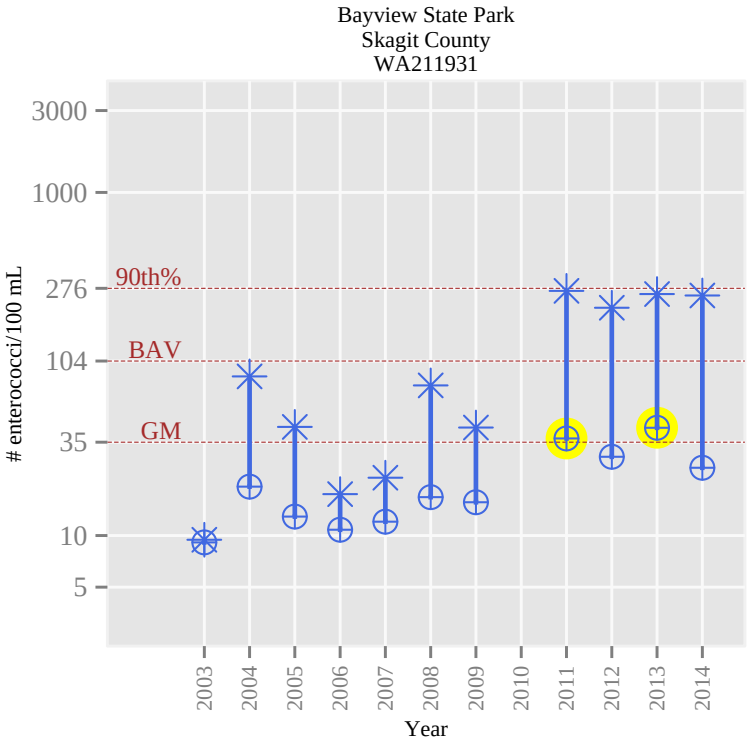

Sunnyside Beach Park
Pierce County
WA872803
3000
1000
276
104
35
10
5
90th%
BAV
GM
# enterococci/100 mL
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year


Titlow Park
Pierce County
WA465917
3000
1000
276
104
35
10
5
90th%
BAV
GM
# enterococci/100 mL
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

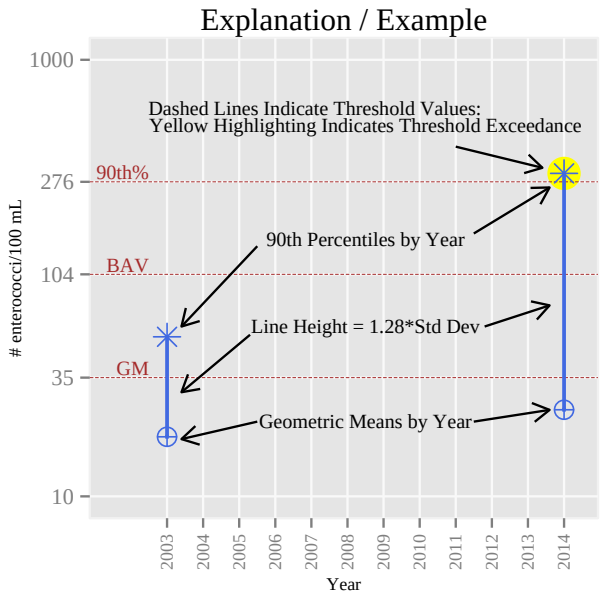

Waterfront Dock / Ruston Way
Pierce County
WA288467
3000
1000
276
104
35
10
5
90th%
BAV
GM
# enterococci/100 mL
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

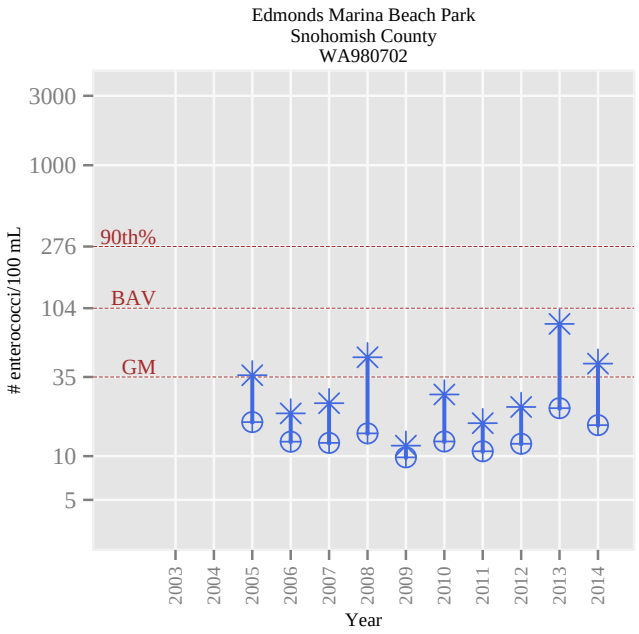
***Skagit County***

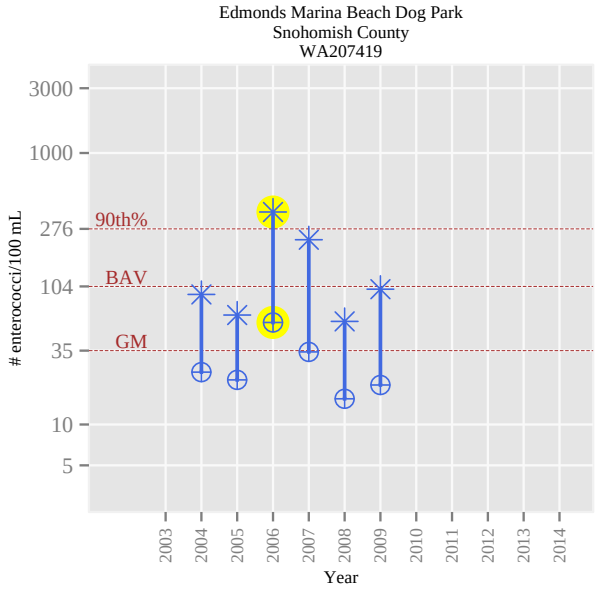


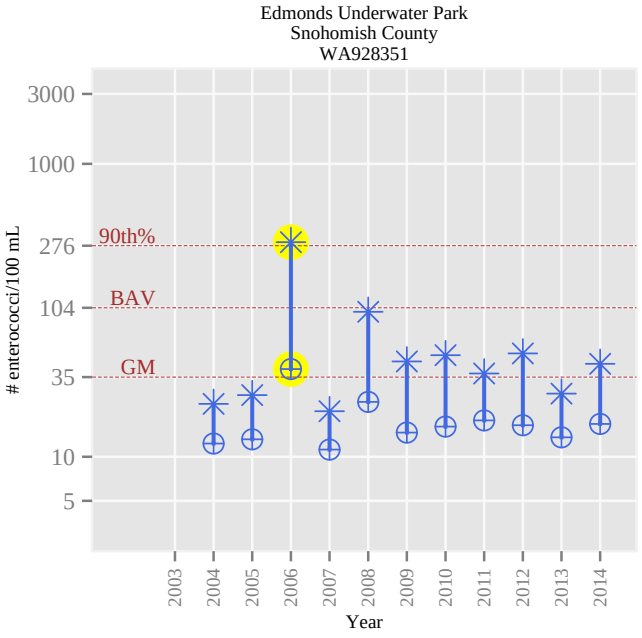



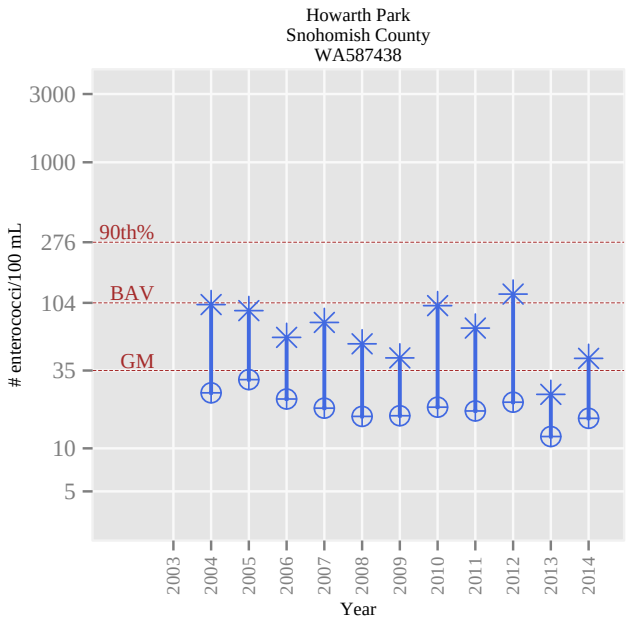
## *Snohomish County*

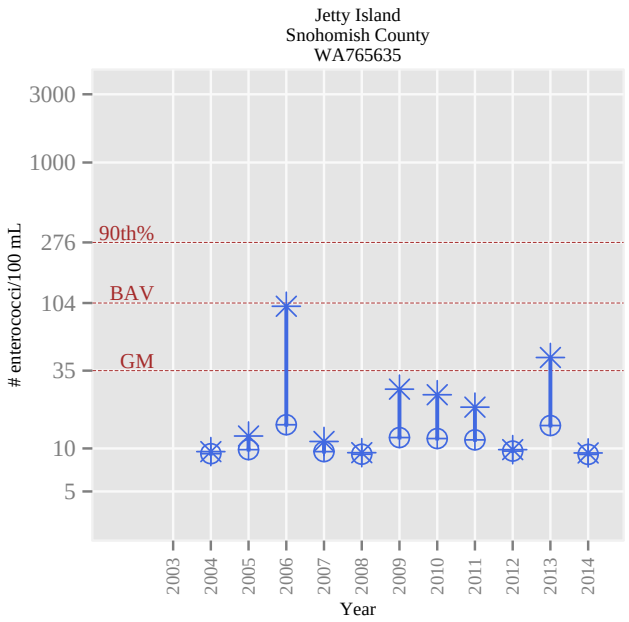


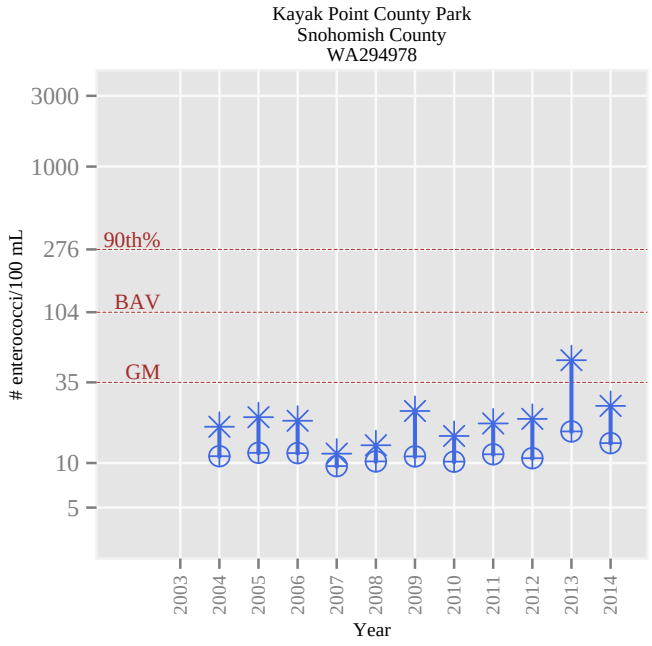



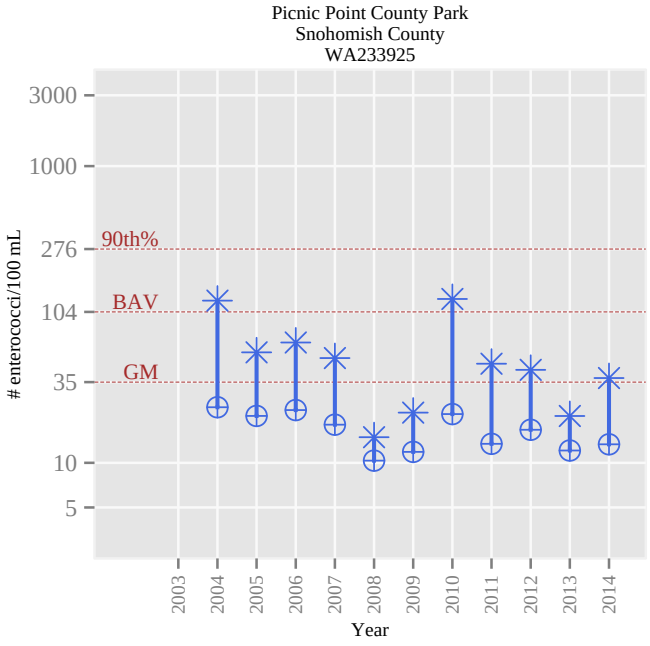



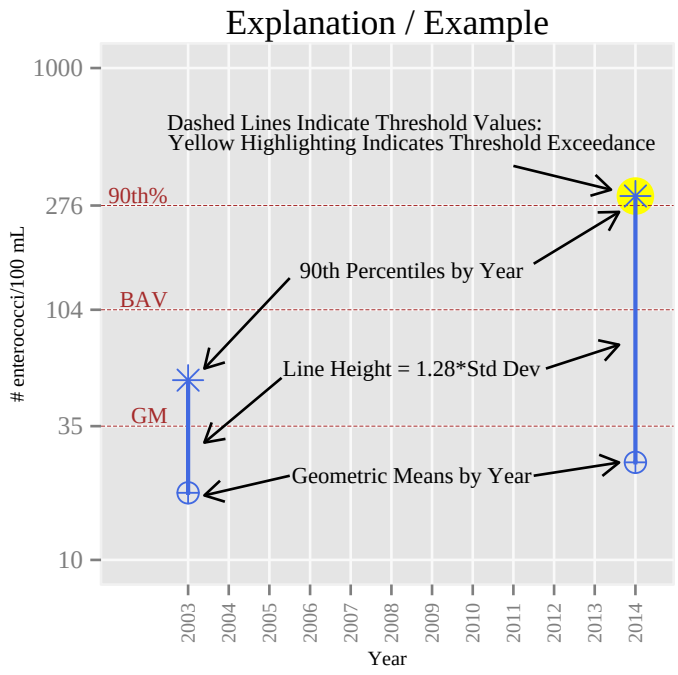

Howarth Park
Snohomish County
WA587438
3000
1000
276
104
35
10
5
90th%
BAV
GM
# enterococci/100 mL
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

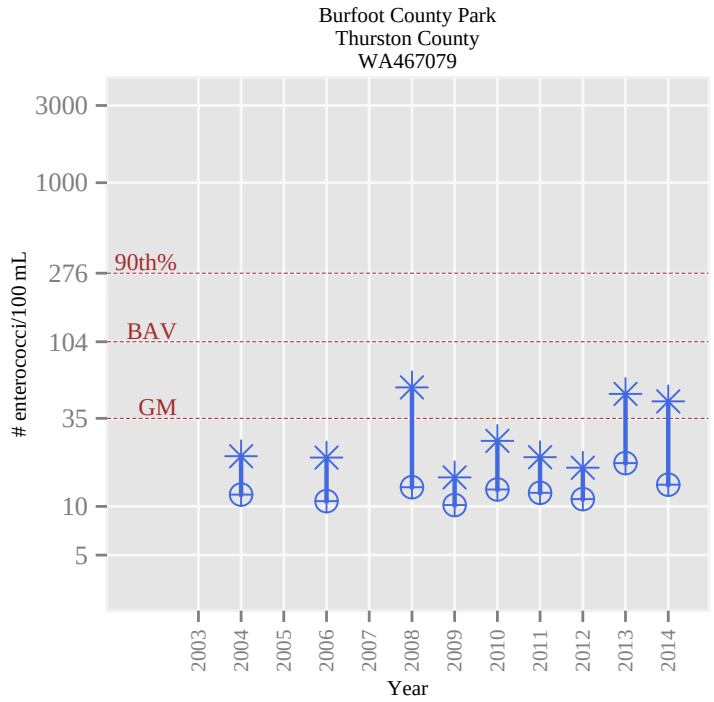

Jetty Island
Snohomish County
WA765635
3000
1000
276
104
35
10
5
90th%
BAV
GM
# enterococci/100 mL
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year


Kayak Point County Park
Snohomish County
WA294978
3000
1000
276
104
35
10
5
90th%
BAV
GM
# enterococci/100 mL
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

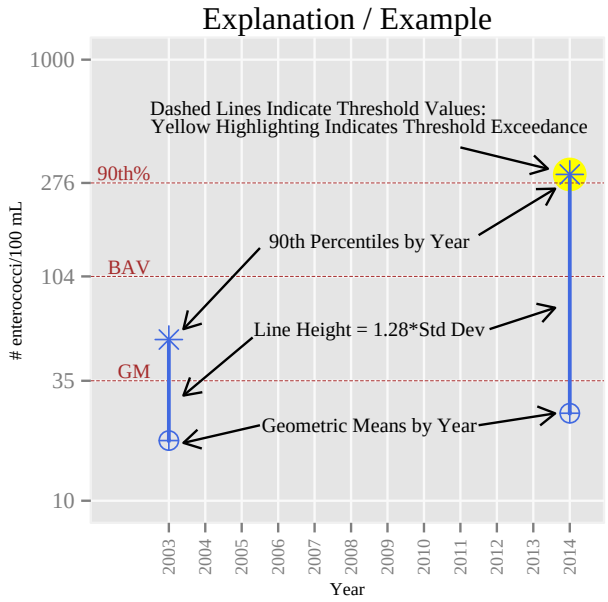

Picnic Point County Park
Snohomish County
WA233925
3000
1000
276
104
35
10
5
90th%
BAV
GM
# enterococci/100 mL
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

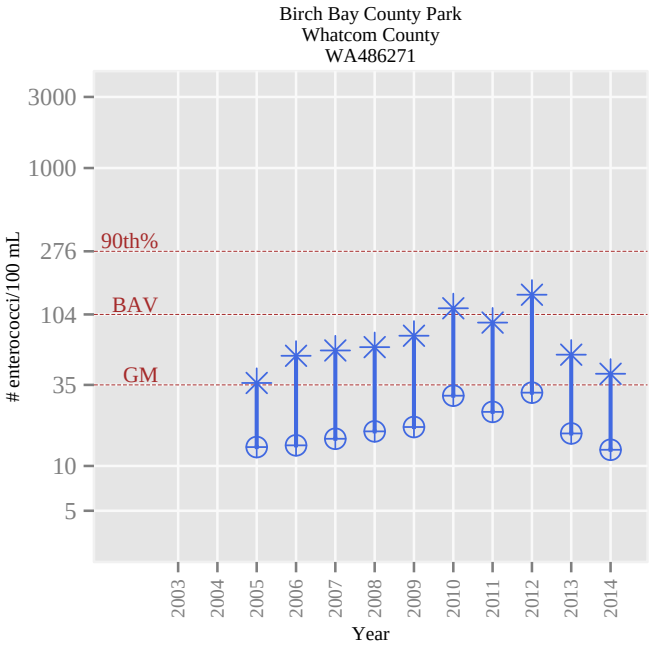
***Thurston County***

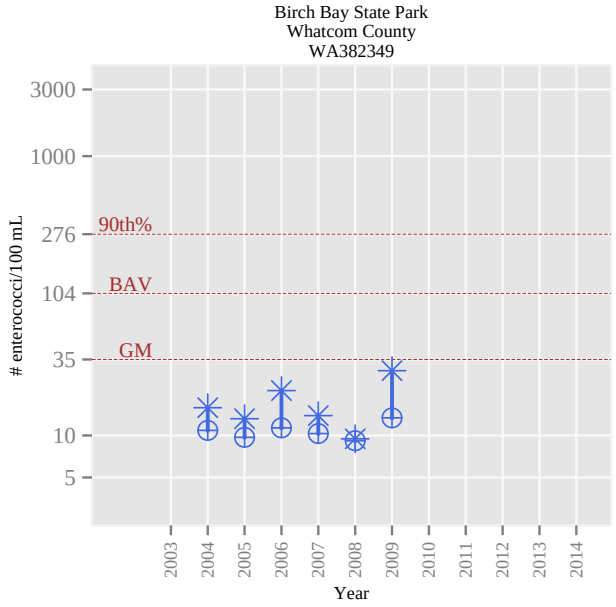


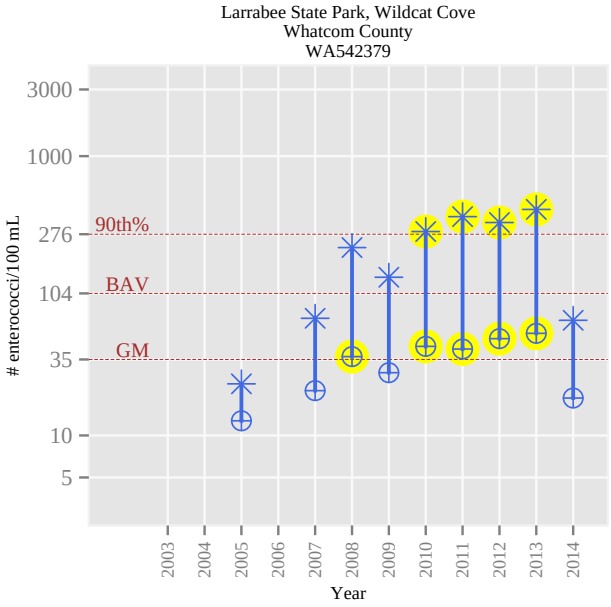



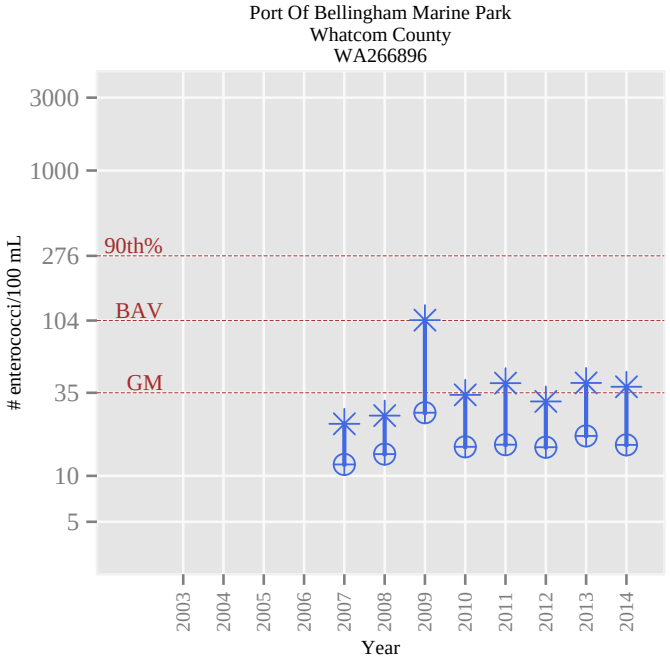
## *Whatcom County*




Port Of Bellingham Marine Park
Whatcom County
WA266896
# enterococci/100 mL
3000
1000
276
104
35
10
5
90th%
BAV
GM
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

# Appendix C. Glossary, Acronyms, and Abbreviations

## Glossary

**Enterococci:** A genus of bacteria that inhabit the intestinal tract of warm-blooded animals and remain viable (alive and capable of infecting another organism) in water for a variable period of time. The presence of enterococcus in water indicates fecal contamination by a warm-blooded animal; harmful bacteria, viruses, or protozoa associated with fecal contamination may also be present.

***Escherichia coli (E. coli*):** A species of bacteria that inhabit the intestinal tract of warm-blooded animals and remain viable (alive and capable of infecting another organism) in water for a variable period of time. While *E. coli* are normally harmless and live in the intestines of healthy people and animals a few strains may cause illness. The presence of *E. coli* in water indicates fecal contamination by a warm-blooded animal; harmful bacteria, viruses, or protozoa associated with fecal contamination may also be present.

**Fecal coliform (FC):** That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

**Geometric mean (GM):** A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000 fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

**Primary contact recreation:** Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

**90th percentile:** An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90th percentile value is a statistically derived estimate of the division between 90% of samples, which should be less than the value, and 10% of samples, which are expected to exceed the value.

## Acronyms and Abbreviations

| | |
|---|---|
| ASTM | American Society for Testing and Materials International |
| BEACH | Beach Environmental Assessment, Communication, and Health |
| BEACH Act | Beaches Environmental Assessment and Coastal Health Act |
| cfu | Colony forming unit(s) |
| Ecology | Washington State Department of Ecology |
| EPA | U.S. Environmental Protection Agency |
| FC | (See Glossary above) |
| GM | (See Glossary above) |
| MPN | Most probable number |
| MQO | Measurement quality objective |
| RSD | Relative standard deviation |
| WAC | Washington Administrative Code |